5-2002

Modeling and Assessment of Environmental Capacity, Dubai Coastal Region, United Arab Emirates

Mohammad Abdul Rahman Hassan Deshgooni

Modeling and Assessment of Environmental Capacity, Dubai Coastal Region, United Arab Emirates

Thesis submitted in partial fulfillment of the requirements for Degree of MSc. in Environmental Science

By

Mohammad Abdul Rahman Hassan Deshgooni

Deanship of Graduate Studies
Environmental Science Program
United Arab Emirates University

May 2002

The Thesis of Mohammad Abdul Rahman Hassan for the Degree of Master of Science in Environmental is approved.

....

Examining Committee Member, Dr. Amr Abdel Aziz El-Sammak

....

Examining Committee Member, Dr. Fadel El-Sadouny

....

Examining Committee Member, Dr. Abdul Nabi Al-Ghadban

....

Dean of the Graduate Studies, Dr. Hadef Rashed Al-Owais

United Arab Emirates University
2001/2002

Supervisors

1. Dr. Amr El-Sammak

   Assistant Professor of Marine Geology

   Geology Department

   Faculty of Science

   United Arab Emirates University

2. Dr. Fathy H. Mohamed

   Associate Professor of Geochemistry

   Geology Department

   Faculty of Science

   United Arab Emirates University

ACKNOWLEDGMENTS

I would like to extend my sincere thanks and gratitude to my country and the great university that I have been studying in for several years with the leadership of H.E. Sheikh Nahayan Bin Mubarak Al-Nahayan.

I would like to thank my thesis senior supervisor, Dr. Amr El-Sammak, Geology Department, for his supervision, encouragement, invaluable advice and support through the thesis. I feel indebted to him for his stimulating guidance, valuable suggestions and for the critical reviewing of the manuscript.

My thanks would be also for co-supervisor Dr. Fathy H. Mohammed, Department of Geology, for his supervision, patience and the critical reviewing of the manuscript.

I would like also to thank Dr. Shahid Mustafa, environmental officer, Dubai municipality for his extensive help during this work.

I would never forget the encouragement I received from: Eng. Hamdan Al Shaer, Director of Environmental Department, and Eng. Redha H. Salman, Head of Environment Protection and Safety Section, Environment Department, Dubai Municipality for this work.

My thanks are extended to Miss. Buthaina A. Saleh, Mrs. Lily George and the staff of Environmental Lab Unit of Dubai Central Laboratory of Dubai Municipality for their help in analyzing the samples.

My thanks also are due for Mr. Aymen Al-Saee for his help in doing X-ray diffraction.

My thanks will be also for Dubai Municipality for providing the samples, captains and inspectors of marine environment and Sanctuaries Unit, Environment Department, Dubai Municipality for their assistance during fieldwork.

Finally, I wish to express my thanks to my family for their continuous encouragement & patience.

CONTENTS

*****

List of Tables

*****

List of Figures

ABBREVIATIONS

APHA	American Public Health Association
FAO	Food and Agriculture Organization of the United Nations, Rome
GWDB	Groundwater pump, Dubai Side
IAEA	International Atomic Energy Agency, Vienna
IMO	International Maritime Organization, London
MNR	Marine National Report
PSTN	Pumping Station
ROPME	Regional Organization for the Protection of Marine Environment, Kuwait
STP	Sewage Treatment Plant
SWDB	Strom water Drainage, Dubai Side
SWDR	Storm water Drainage, Deira Side
UN	United Nations, New York
UNEP	United Nations Environmental Programme, Nairobi
UNESCO	United Nations Educational Scientific and Cultural Organization, Paris
UNDR	Underpass Drainage
USEPA	United States Environment Protection Agency
WHO	World Health Organization
WMO	World Meteorological Organization, Geneva

*****

ABSTRACT

The area investigated covers Dubai Creek in the Arabian Gulf. Ten stations were selected for the study, covering the maximum fragments of the Creek. The assessment of environmental capacity indicated the presence of at least two distinctive regions along the Creek. The area located between Stations 1-3 is the downstream region; while the area laying between Stations 4-10 is the upstream region.

Water samples were analyzed for: physico-chemical parameters (Water Temperature, pH, Salinity, Dissolved Oxygen, and Turbidity); and nutrients (Total Nitrogen, Nitrate-nitrogen and Phosphate-phosphorus). Whereas the surface sediments were analyzed for: Moisture Content, Organic Carbon, and Texture analyses; as well as Heavy Metals (Copper, Nickel, Lead, Zinc, and Chromium) content.

In the water column, towards the southwest area of the Island along the upstream region of Dubai Creek, low salinity values clearly indicate the influx of fresh water. The levels of nutrients such as total nitrogen, nitrate-nitrogen and phosphate-phosphorus in the surface water are respectively 2.8, 3.5 and 8.8 times higher at the upstream region as compared to the downstream section. As for the surface sediments, a high contents of moisture, organic carbon and mud are evident along the upstream region of the Creek.

Heavy metals such as copper, zinc and lead show a clear plume of high concentrations starting from Station 9. The areas surrounding Station 9 are recognized to be the most contaminated in the upstream region. The surface sediments in Dubai Creek contain 35 times higher levels of lead and zinc than the unpolluted marine sediments in the U.A.E, as recorded in 1993.

***

CHAPTER I

INTRODUCTION

Introduction

1.1 General

Environmental management consists of formulating and applying strategies by which resources of a given ecosystem can be utilized in an efficient and sustainable manner in the context of the overall and specific socio-economic and political goals of the society (GESAMP, 1986). The use of the marine waste must only be undertaken after first conducting as rigorous an assessment as possible of the probable impact. The policy by which this assessment is conducted is based on a comprehensive scientific assessment in which intense scientific data is used. The process by which the final decision is taken often centers as Environmental Impact Assessment. The type of assessment undertaken in environment impact can follow one of two approaches:-

- To make "deterministic" assessment of permissible effluent.
- To perform a probabilistic assessment of the environmental capacity.

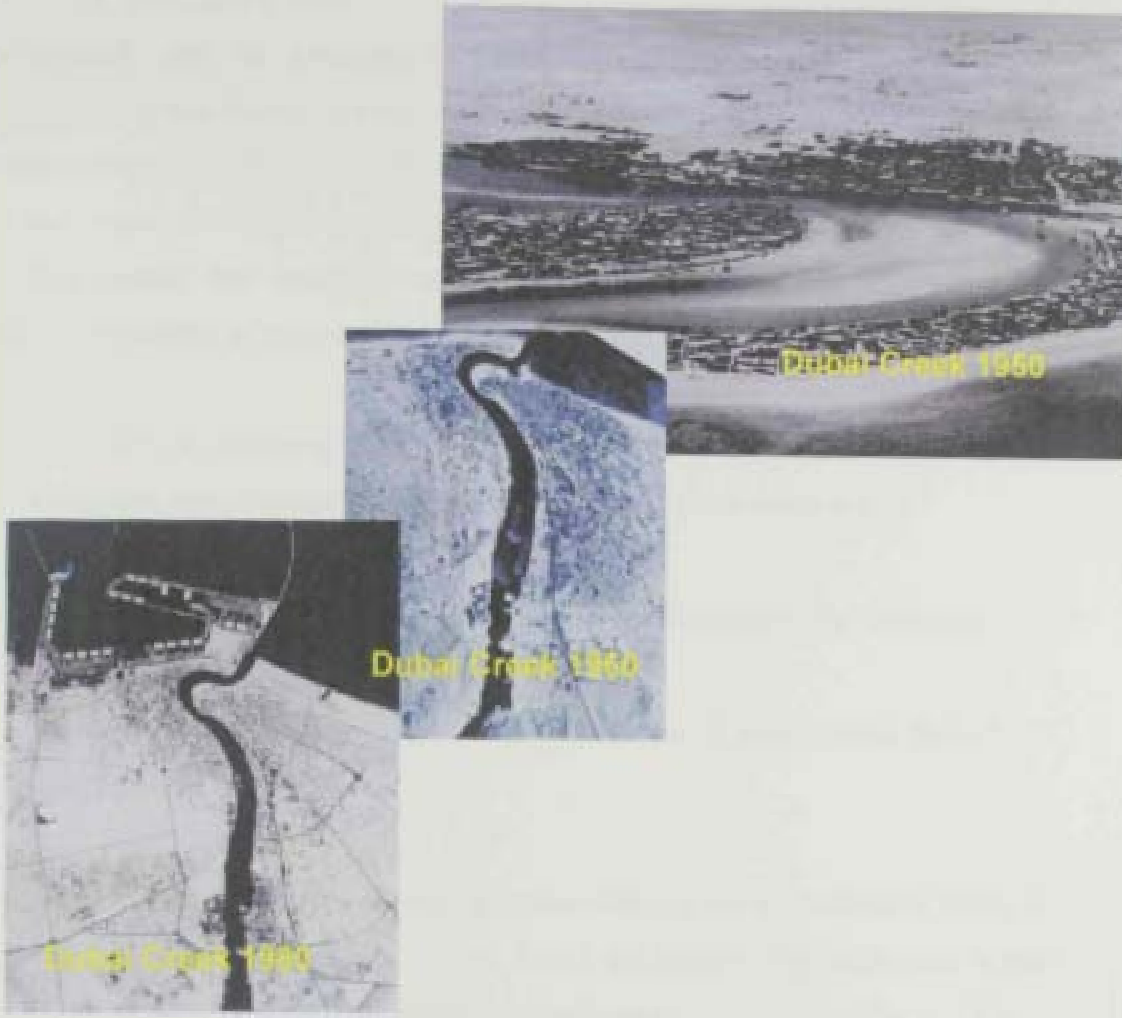
Various terms are used to describe the extent to which the environment is able to accommodate waste without unacceptable effects. One such term is Environmental Capacity. Environmental Capacity is a property of the environment. It is defined as its ability to accommodate a particular activity or rate of activity (e.g., volume of discharge per unit time, quantity of dredging dumped per unit time, quantity of minimum extracted per unit time) without unacceptable impact (GESAMP, 1986). However, the environmental capacity varies with the characteristics of each area, type and number of discharges, activities or affected resources and their uses.

Dubai Creek has attracted human settlement for many centuries, as a fishing hub as well as a trading center. The Creek had the best natural port in the Gulf region and the Arabian Peninsula. The emergence of Dubai as a commercial center is dated back to the beginning of 19^{th} century. The city was a small coastal village, which gradually began to grow. In the 19^{th} century the population of Dubai was approximately six thousand and by the 1930s approached eighteen thousand (Wilson and Shukla, 1999).

In 1940s, Dubai was the largest town on the Trucial Coast with about twenty-five thousands inhabitants. During that period, the Creek divided Dubai town. The length of the Creek was approximately between 8-10 km and many native crafts used to be anchored in the Creek. After the first dredging in the Creek during 1959-60, more ships called in Dubai Creek and opened a new chapter in the commercial life of Dubai. By 1965, a comprehensive plan was made and approved by the Dubai Ruler and amended in 1971 with the help of UNDP (United Nations Development Programme) experts (Wilson and Shukla, 1999). Today the population of Dubai is exceeding 800 thousends. As a relatively young and progressive city it has achieved tremendous development in the last two decades. These developments include in particular, the coastal region (Figure 1.1).

The United Arab Emirates comparise of Abu Dhabi, Dubai, Sharjah, Ajman, Umm Al-Qaiwain, Ras Al-Khaimah and Fujairah. The second largest emirate in the seven-member federation, Dubai is the center of trade, commerce and tourism in the United Arab Emirates. It is also the leading entry port to the region.

The United Arab Emirates lies between latitude 22^{o}-26.5 ^{o} North and longitudes 51^{o}-55.6 ^{o} east. It has 700 kilometers of coastline and the 77,700 sq km land area is dominated by rolling sand dunes and gravel plain. Dubai's coastaline stretches about 72 kilometers along the southern shores of the Arabian Gulf.



Photos Courtesy: Planning and Survey Department, Dubai Municipality

Figure 1.1 *Dubai Creek (Historic development through the years)*

Dubai is developing rapidly and many developmental activities are concentrated around Dubai Creek. As a result, the natural ecosystem is being degraded and there is an increasing threat to its vigour and productivity. Hence arises an urgent need to formulate marine environmental modeling and assessment.

An essential step in assessing the environmental impact of a discharge is the determination of boundaries within which the ecosystem is impacted. There are three types of boundaries identified:- an enclosed type, a semi-enclosed type, and open coast type. Dubai Creek can be classified within the first category "Enclosed type". This usually has restricted exchange of water and is most amenable to definition of boundries of impacted ecosystem.

This work aims at studying the fate and behaviour of some trace metals in the surface sediments from Dubai Creek. The specific aims of this study are:-

- determination of some environmentally important toxic metals in the sediments;
- determination of "pollution load index" as well as the "contamination factor" for the studied metals;
- to produce answer of management questions with adequate confidence limits in order to formulate new policies of land based discharges or amendments in the existing regulations of waste discharges into the Creek.

1.2 Review of Literature

Information on the physico-chemical oceanographic characteristics are expanded in the Regional Organization for Protection of Marine Environment (ROPME) Sea Area of the Arabian Gulf (Grasshoff, 1976; Brewer, *et al.*, 1978; Brewer and Dyrssen, 1985; Hunter, 1986 and Dorgham and El-Gindy, 1991).

Studies conducted by the researchers on the Arabian Gulf and the Gulf of Oman provide data on bottom sediments (Ross, 1978); and biological characteristics (Grice, 1978). Several other studies were executed reporting heavy metals levels in northwest region of the Arabian Gulf (Saad and Hussein, 1978; Andreni *et al.*, 1982 and Al-Hashmi and Salman, 1985) and coastal waters of Oman (Fowler, 1985). The worldwide review on heavy metals and chlorinated hydrocarbons in the marine environment shows the minimum, maximum and average limits of lead and cadmium in the surface sediments of the Arabian Gulf (Fowler, 1990).

Recent reports on heavy metals in sediments have also been documented in Kuwait (MNR-Kuwait 1999), Oman (MNR-Oman 1999), Qatar (MNR-Qatar 1999) and Bahrain (MNR-Bahrain 2000).

The trace metal determination was also covered during the contaminant screening survey of International Atomic Energy Agency (IAEA) during 1998 (IAEA, 1999). This survey covered many locations in Saudi Arabia, Kuwait, Qatar and the United Arab Emirates.

There are only little published materials on the modeling and assessment of environmental capacity from the Arabian Gulf and practically none on Dubai Creek. None of the references of such a study could be acquired for Dubai Creek. However, some studies show the oceanographic and mathematical modeling for the Kuwait Action Plan (UNESCO, 1984; UNEP, 1985). The extensive assessment on Environment Capacity (GESAMP, 1986) and Coastal Modeling (GESAMP, 1991) have been reviewed by IMO/FAO/UNESCO/WMO/WHO/IAEA/UN/UNEP and Joint Group of Experts on the Scientific Aspects of Marine Pollution (GESAMP).

Substantial amount of information on water quality during different seasons provided physico-chemical and biological conditions of Dubai Creek water body (Dubai Municipality, 2000a). Other studies provided data on rainfall and inputs of pollutant during the runoff period in Dubai Creek during 1995-96 (Dubai Municipality, 1996a) and 1996-97 (Dubai Municipality, 1997a).

A study on the Evaluation of the current environmental situation along various stretches of Dubai Creek and the environmental impacts resulting from proposed developments has been conducted by the Dubai Municipality (Halcrows, 1992). This study includes hydrodynamics, evaluation of discharges, marine and terrestrial surveys, and statistics on the water quality and sediment analyses.

The report on "Mass mortality of fish *Nematalosa nasus* in the lagoon of Dubai Creek" presents detail on a fish mortality incident (Dubai Municipality, 1995a) while the study "Biological characteristics of the marine environment in Dubai" (Dubai Municipality, 996b) provides statistics on water quality and biological characteristics of Dubai Creek.

The study on macrobenthic communities near the sewer outlets in Dubai Creek provides some information on water quality of Dubai Creek (Ismail, 1992). Another work on twenty-four stations of the United Arab Emirates coastline (Shriadah and Al-Ghais, 1999) gives information on physico-chemical water quality characteristics.

1.3 Area of Study

Dubai "Pearl of the Arabian Gulf" is a well known statement since old history. The city of Dubai is bisected by Dubai Creek. The Creek, which extends inland for 14 km from its entrance to the Arabian Gulf, varies in width from approximately 100 meters near the mouth to 1.2 km at its end with a depth variation of 5.5 to 8 meters. Today, it remains an appealing focus around which the city continues to grow (Figure 1.2).

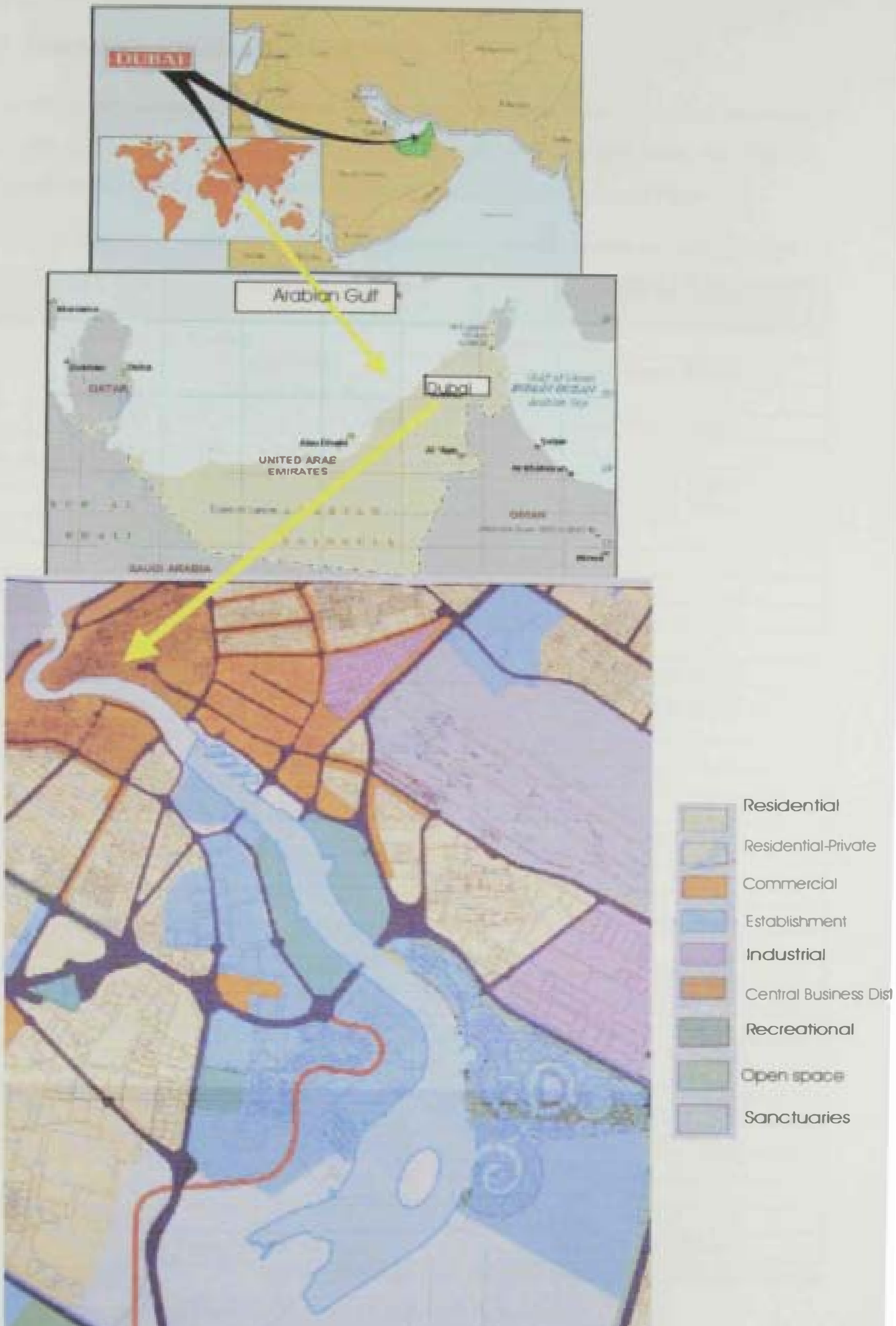
Dubai Creek, *downstream*

Dubai Creek, *upstream region*

Photos Courtesy : Public Relation Section, Dubai Municipality

Figure 1.2 *Arial view of Dubai Creek from downstream and upstream regions during 2000*

Dubai Creek is a seawater intrusion system from the Arabian Gulf, it passes through an open urban landscape that makes tight U-turn around Al Ras band with no hydro-dynamically significant freshwater inputs (Figure 1.3). The tidal current increases towards the mouth of Creek. The peak velocity occurs where the cross sectional area is minimum. Just as the current speed increases towards the mouth of the Creek, so there is a converse reduction towards the head of the lagoon.



Source: Planning and Survey Department, Dubai Municipality

Figure 1.3 *Dubai Creek - location and land uses*

1.4 Discharge Inputs into the Creek

There are many recognized sources of inputs into the Creek such as treated wastewater from the Awir STP, surface runoff during rainfall, raw sewage from the 'dhows', untreated waste and discharges from dewatreing outfalls (Table 1.1 and Figue 1.4).

Table 1.1 *Details of wastewater outfalls*

Outfall No.	Outfall name, Source and Location	Discharge quality
1	From Fish Market	Ground water
2	SWDR 6, PSTN near MMI	Ground water, Storm Water
3	UPDR 9, near Middle East Bank	Ground Water
4	SWDR 8 PSTN Diera Post Office	Ground Water, Storm Water
5	SWDR 1&2 near Carlton Tower	Ground Water
6	SWDR 17 Wharfage Pool No.1	Ground Water, Storm Water
7	SWDR 3 Wharfage Pool No.3	Ground Water, Storm Water
8	From Clock Tower Area	Storm Water
9	SWDR 4	Storm Water
10	From Airport Cargo Village	Storm Water
11	From Golf Club	Ground Water
12	From Air Port	Storm Water
13	Ground Water Pump 1-4 & 6-7	Ground Water, Storm Water
14	SWDR 9&11 Rashidya	Ground Water, Storm Water
15	From Air Port	Storm Water
16	SWDR 14 From Rashidya	Storm Water
17	From Rashidya	Storm Water
18	Sewage Treatment Plant, Aweer	Treated effluent
19	Aweer Industrial Area	Ground Water, Storm Water
20	From Nadd Al Sheba	Ground Water Dewatering
21	From Shk. Mohammed Palace	Ground Water Dewatering
22	From Zabeel Area	Ground Water Dewatering
23	Abandoned line	-
24	Al Jaddaf Dock	Surface/Untreated wastewater
25	Old STP I	Strom water during rain
26	Old STP II	Storm water during rain
27	From Creek Side Area	Ground Water, Storm Water
28	From Court Complex Area	Ground Water, Storm Water
29	SWDB1 From Karama Area	Ground Water, Storm Water
30	From Al Seaf Road	Ground Water, Storm Water
31	PSTN B14	Storm Water
32	PSTN B15	Storm Water
33	GWDB1	Storm Water
34	SWDB 5 From Ghubaiba Area	Ground Water, Storm Water

Source: Drainage and Irrigation Department,Dubai Municipality

NB. Outfalls numbers correspond to the numbers shown in figure 1.4

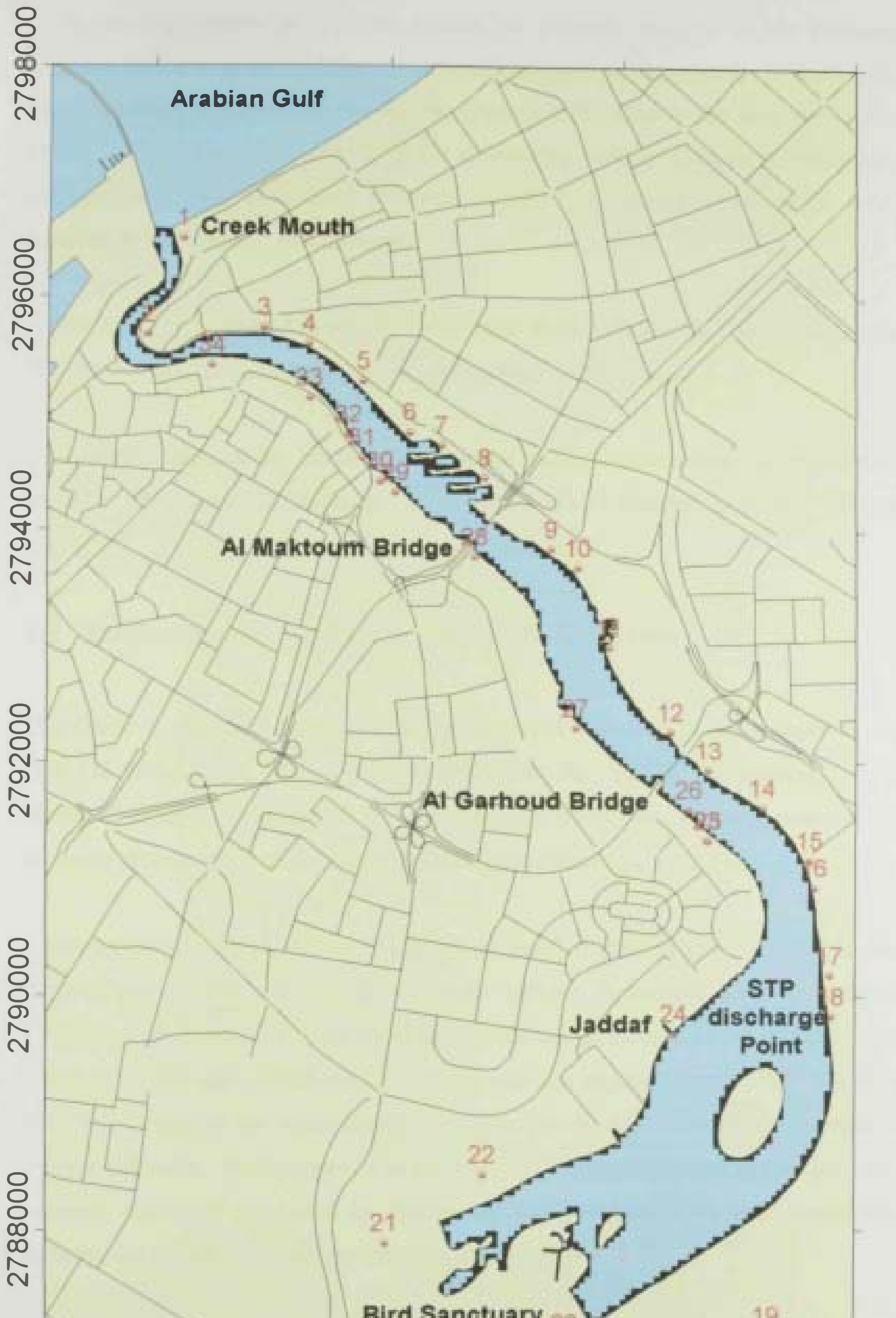


Figure 1.4 *Wastewater outfalls location along Dubai Creek*

Dewatering outfalls, as the name implies, are primarily intended for the discharge of groundwater originating from construction operations. A network of perforated pipes has been developed to restrict the groundwater level in the area (Halcrows, 1992). The quality of effluent from the dewatering outfalls is similar to the quality of seawater. Few discharges, however contain high amount of dissolved solids resulting in high salinity and nitrogen.

The quantity of treated wastewater discharge from STP into the Creek varies from 20,000 to 40,000 cubic meters per day depending on the season.

Although, there is no identified industrial effluent connection to the Creek, however the untreated discharge from outfall No.24 (Jaddaf) is evident into the Creek.

1.5 Environmental Characteristics of Dubai Creek

The Creek is generally an alkaline water body and maintains similar salinity to the Gulf (38-40‰). The portion of the Creek from the Arabian Gulf entrance to Al Maktoum Bridge is considered to have generally good water quality; containing a relatively diverse range of marine organisms (Dubai Municipality, 2000b).

The area beyond Al Garhoud Bridge to the head of Dubai Creek contains higher levels of nutrient and trace metals due to the effluent discharges from Outfall No. 18 (Awir STP), Outfall No. 24 (Jaddaf), Outfall No. 16 (Rashidya), Outfall No. 20 (Nadd Al Sheba) and Outfall No.22 (Zabeel) into this region (Figure 1.4). The high level of nutrients in the water causes the formation of algal bloom and the system become eutrophic. Furthermore, Outfall No. 24 poses another threat to the water and sediment quality of the Creek by discharging heavy metals from ship repairs and maintenance industry (Dubai Municipality, 2000b) (Figure 1.3).

***

CHAPTER II

MATERIALS AND METHODS

Materials and Methods

2.1 Sampling Methodology

Sampling of water and sediments were conducted on board "Research Vessel Yamaha™" equipped with modern oceanographic sampling devices as well as Global Positioning System, and 3D Echosounder.

Data on water and sediment samples were collected from 10 locations along Dubai Creek (Table 2.1 and Figure 2.1) during January 1999- December 2000.

For the purpose of this study, Dubai Creek is divided into two section, following Halcrows (1992). The lower Creek is the area from Creek mouth to Al-Maktoum bridge wheras and the upper Creek is the area south of Al-Maktoum bridge till Creek end. These areas has been divided according to the hydrodynamics of the Creek (Halcrows, 1992).

According to the hydrodynamics model proposed by Halcrows *(op. cit.),* the Creek will be divided into the upstream region which includes station numbers 1-3, and the downstream region which includes the station numbers 4-10.

2.2. Sampling Frequency

Water quality and surface sediment samples were collected from 10 locations in Dubai Creek; whereas the core samples for mineralogical analysis were collected from the upstream region (stations 4-10) of Dubai Creek. Core samples from the downstream region (stations 1-3) could not be collected due to the hard sandy bottom.

Table 2.1 *Sampling stations along Dubai Creek*

Stations	Location	Stations	Location
1	Creek Mouth	6	Island West
2	Abra	7	Island South
3	Al Maktoum Bridge	8	Island East
4	Al Garhoud Bridge	9	Jaddaf
5	Island North	10	Sanctuary

Monthly monitoring (surface, middle and bottom) of water quality were conducted *in situ* to study the following physico-chemical parameters:-

- Temperature
- Salinity
- pH
- Dissolved Oxygen

Quarterly surface water samples were collected and measured the following parameters.

- Turbidity
- Total nitrogen
- Nitrate-nitrogen
- Phosphate-phosphorus

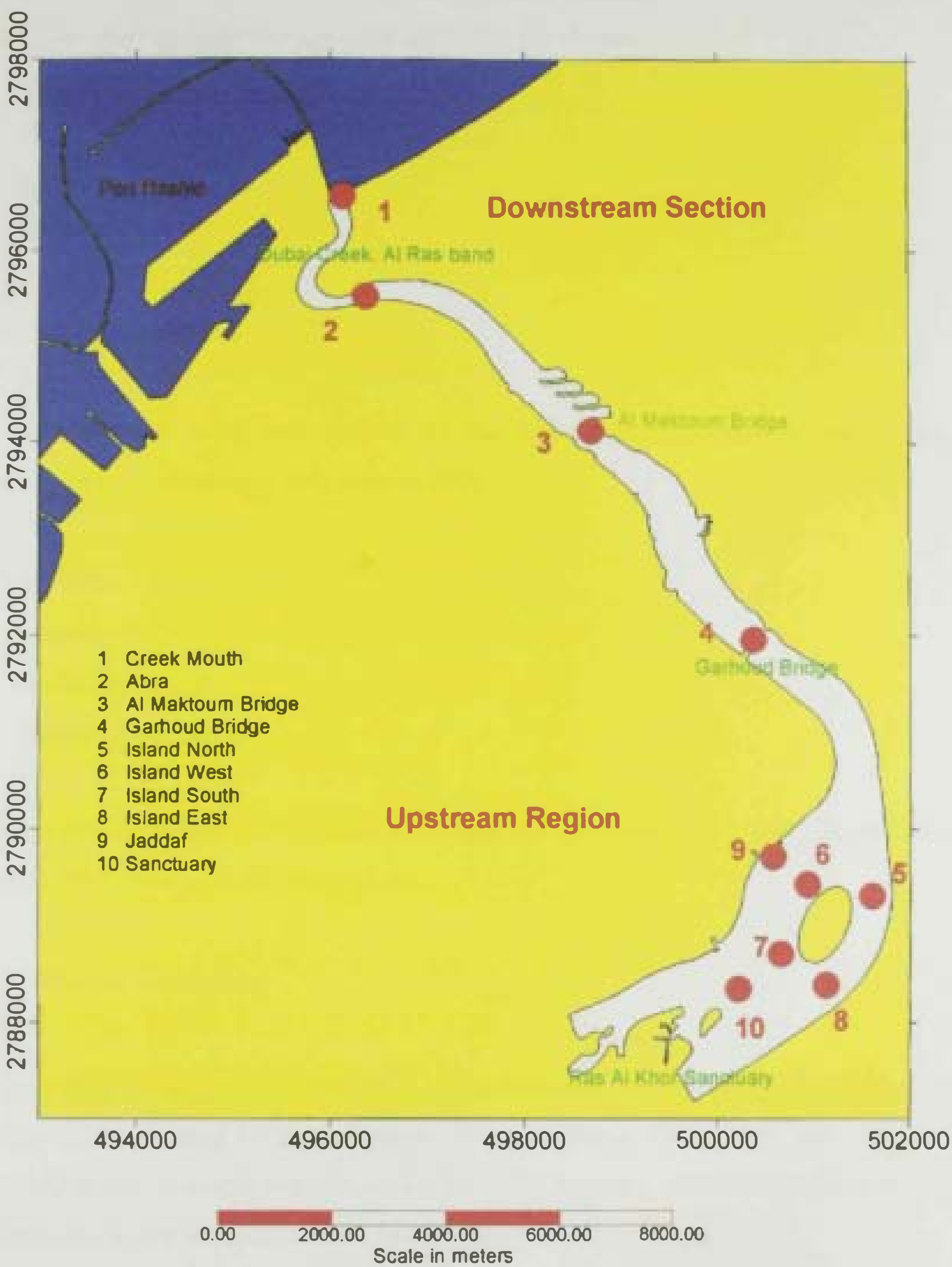


Figure 2.1 *Monitoring stations along Dubai Creek*

Annual surface sediments for the year 1999 and biannual surface sediments for the year 2000 were collected to study the following heavy metals: -

- Copper
- Lead
- Nickel
- Zinc
- Chromium

On the other hand the analyses of the following parameters in the surface sediments were conducted only once in 2000: -

- Moisture Content
- Organic Carbon
- Sediment Texture
- Sediment Mineralogy

The data from Jabal Ali Sanctuary (Located on the coastal line of Dubai), collected during 1997 was used for comparison.

2.3 Water Sampling

Plastic Niskin water sampler made by Hydro-bios with closing mechanisms at desired water depth was used for the collection of water samples. The samples were collected in high density polyethylene plastic bottle of 1L capacity, preserved in ice box and transferred to the laboratory immediately after the collection.

2.4 Sediment Sampling

Stainless steel Van Veen sediment sampler made by Hydro-bios™ was used for obtaining bottom sediments. The samples were collected in acid rinsed polyethylene bags, freeze-dried and prepared for analysis.

2.5 Methods of Analysis

2.5.1 Water Quality - Physico-chemical Parameters

Water quality monitoring was conducted *in situ* with respect to the following parameters at the surface, middle and bottom layers of water by using USEPA approved "Hydrolab H20™" and "DataSonde 4™" water quality monitoring equipments. Equipments were pre-calibrated with the specified standards prior to the monitoring of following parameters.

Parameter	Accuracy
Temperature	± 0.1 °C
Salinity	± 0.2 ‰
pH	± 0.2 Unit
Dissolved Oxygen	± 0.2 mg/ℓ

2.5.2 Water Quality -Turbidity and Nutrients Parameters

2.5.2.1 Turbidity

Turbidity was measured by Nephelometric Method (APHA, 1995). The measurements were carried out immediately using the nephelometer turbidity meter after gently agitating and removing air bubble from the sample.

2.5.2.2 Total Nitrogen

Total nitrogen was measured by the following method (Parsons *et al.*, 1984).

Samples of seawater are oxidized with potassium persulfate under pressure converting organic nitrogen to nitrate. The nitrate was then analyzed as per the following equation

$$N/l = (E \times F) - A,$$

Where:

E : the corrected sample extinction

F : the factor

A : the nitrate and nitrite originally present in seawater

2.5.2.3 Nitrate-nitrogen

Nitrate nitrogen was determined by Ion chromatography method (APHA, 1995). Only ion chromatography provides a single instrumental technique that may be used for its rapid, sequential measurement.

A series of standard nitrate solution were prepared by weighing 1.3707g of $NaNO_3$ salt dried to a constant weight at 105 ^{o}C, to 1000 ml. When necessary the sample particulate was removed by filtering from 0.2μm membrane filter paper. Enough samples were injected to flush sample loop several times. Switched on ion chromatograph from load to inject mode and record peak heights and retention times on stripe chart recorder.

Concentration of nitrate were calculated according to the following equation in milligram per liter by referring to the appropriate calibration curve.

$$C = H \times F \times D$$

Where:

C : concentration in mg nitrate/ℓ

H : peak height

F : response factor concentration of standard

D : dilution factor for sample

2.5.2.4 Phosphate-phosphorus

Phosphate-phosphorus was determined using Stannous Chloride method (APHA,1995). Molybdophosphoric acid was formed and reduced by Stannous Chloride to intensively colored molybdenum blue. The concentration was measured by colour photometrically at 690 nm and compared with calibration curve. The value of Phosphate-phosphorus was measured by the following equation.

$$\text{mg P}/\ell = \text{mg P (approximately in 104.5 ml final volume)} \times 1000/\text{ml sample}$$

2.5.3 Sediment Quality

2.5.3.1 Moisture Content

Known amount of pre-weighed sediment samples were dried at 80 $^{\circ}$C for 48 hours and then weighed. The moisture content is calculated by the difference of pre-weighed and dried weighed sediments.

2.5.3.2 Organic Carbon

Organic matter expressed as percent Organic Carbon was estimated using acid dichromate and back titration method (Gaudette *et al.*, 1974). The precision and accuracy of the results were checked by applying the same procedure on triplicate of some selected samples.

2.5.3.3 Texture Analysis (Mud and Sand)

The pre-weighed dried sediment was sieved for grain size distribution using a standard size of sieve to determine the amount of Sand (>63 μm) and Mud (<63 μm) in the sample (Loring and Rantala, 1991).

2.5.3.4 Mineralogy

A Philips X-ray diffractometer model PW/1840, with Ni filter, Cu-Kα radiation (λ=1.542 A$^{\circ}$) at 40 KV, 30 mA and scanning speed 0.02°/S was used. The differential peaks between $2\theta=2°$ and $2\theta=60°$ were recorded. The corresponding spacing (dA°) and reactive intensities (I/I°) were calculated and compared with the standard data.

2.5.3.5 Heavy Metals (Copper, Nickel, Lead, Zinc and Chromium)

The heavy metals in the sediments were analyzed as per the specification provided in the Manual of Oceanographic Observation and Pollutant Analyses (MOOPAM, 1999), and APHA standard methods (Section 3111) for the analysis of trace metals by using the standard reference material (APHA, 1995).

Precise and accurate atomic absorption analyses for the determination of metals involved the use of flame (FAAS) and graphite furnace atomic absorption spectrophotometry (GFAAS).

The analysis method used by MOOPAM (1999) is as follows:

Samples are digested with strong acids (Nitric acid and perchloric acid). Atomic absorption spectroscopy resembles emission flame photometry in that the sample solution is aspirated into a flame and atomized. In case of flame Atomic Absorption Spectroscopy, a light beam is directed through the flame, into a monochromator, and onto a detector that measures the amount of light absorbed by the element in the flame. Each metal has its own characteristic wavelength so a source hallow cathode lamp composed of that element is used. The amount of energy absorbed at the characteristic wavelength is proportional to the concentration of the element in the sample.

In case of flame emission, the amount of light emitted at the characteristic wavelength for the element analyzed is measured.

$$C\ (\mu g/g) = \frac{(Cd-Cb) \times F \times V}{W}$$

Where:

C : concentration of element in the original sample (μg/g dry weigh)

Cd : concentration of element in sample solution (μg/ml).

Cb : mean concentration of element in reagent blanks (μg/ml).

F : dilution factor if needed (=1 in case of no further dilution than initial dilution during digestion procedure).

V : volume of dilution of digested solution (ml)

W : dry weight of sample (g)

2.5.4 Modeling and Statistical Applications

"SURFER 7.01™" Software package was used to prepare the two-dimensional distribution model of Dubai Creek.

"STATISTICA™" was used to provide a mta multivariate analysis of the data such as factor analysis, cluster analysis, scatter plot, and correlation.

"EXCEL 2000™" was used for plotting the charts of water and sediment quality parameters.

"SMART DRAW™" was used to compose the location map of Dubai Creek.

***

CHAPTER III

Results and Discussion

WATER QUALITY

Water Quality

3.1 Introduction

Knowledge on the physico-chemical characteristics of an aquatic environment is of great importance. Dubai Creek as a seawater lagoon with no hydrodynamically significant freshwater input, responds rapidly to the external changes particularly climatic. The tidal current at any point depends upon the local cross-sectional area, the water surface area, and the instantaneous rate of changes of tidal elevation. Therefore, the tidal-current velocities increase towards the mouth of the Creek, and are greatest where the cross-sectional area is minimum. The upstream region of the Creek has a wide cross-sectional area, which acts slow rate of tidal elevation and current velocity. The water quality, for that reason, inextricably linked to the hydrological process, thus, the Creek does not behave as a simple aquatic system but also as a part of complex system, which has been influenced by hydrodynamical process.

Some characteristics such as rainfall, which is constantly low with only a few exceptions, keeping Dubai Creek at the edge of two or more global weather systems. The northern '*shamal*' winds in winter blow over the shallow water causes falling water temperature to values more usually associated with temperate oceans, sometimes causing massive mortality of the tropic biota.

The Arabian Gulf waters mainly influences the physico-chemical characteristics of Dubai Creek. The Gulf is a gradual descent to a trough in the north, which runs roughly parallel to the Iranian coast. In both the summer and winter months, the evaporation is extensive, particularly in the very shallow southern embayment, along U.A.E coast. Water enters into the Gulf through the Strait of Hormuz at a salinity of 36.5-37.0 ‰ (Sheppard *et al.*, 1992).

The more inclusive records pertaining to hydrographic structure of the Arabian Gulf region have been obatined from the studies carried out by the different research vessels such as Atlantis II from Woods Hole Oceanographic Institute and NOAA (National Oceanic and Atmospheric Administration) ship (Brewer *et al.*, 1978, and Reynolds, 1993).

Some information with the environmental aspects during the Gulf war of 1991 (El-baz and Makharita, 1994) and its aftermath assessment (Sadiq and McCain, 1993) are also available.

Most of the published information on the physical oceanographic characteristics are confined to the Arabian Gulf by few authors (e.g., Grasshoff, 1976; Brewer and Dyrssen, 1985; Hunter, 1986; Dorgham and El-Gindy, 1991; and El-Gindy and Dorgham, 1992).

The water circulation model, namely denser water flowing outward beneath the inflowing shallow water has also been studied comprehensively in the Arabian Gulf by Hunter (1986).

Information on the physico-chemical characteristics on Dubai Creek is limited. However the routine information on the physico-chemical monitoring records has been published by the Environment Protection and Safety Section (EPSS) of Dubai Municipality in a form of seasonal bulletin and annual reports (Dubai Municipality, 2000a; 2000b). Other research reports such as Fish Mortality (Dubai Municipality, 1995a) Biological Characteristics (Dubai Municipality, 1996b); Rain Runoff (Dubai Municipality, 1996a, 1997a); Eutrophication (Dubai Municipality, 1997b); Algal Blooms (Dubai Municipality 1997c) and assessment of eutrophication and development strategy of Dubai Creek (Salman, 1999). Some physico-chemical parameters of the mid-depth samples, during different tide levels in Dubai Creek, have also been studied by Dubai Municipality during the improvement of Dubai Creek study in 1991 (Halcrows, 1992). Physico-chemical characteristics of Dubai Creek has also been reported in a study of macrobenthic invertebrates near sewer outlets (Ismail, 1992). The record on the environmental characteristics along the U.A.E coastline has been documented from twenty-four stations by Shriadah and Al-Ghais, (1999) during 1993 to 1994.

In the present study a systematic survey of all relevant physico-chemical parameters were considered for the first time to interpret and assess the environmental conditions along Dubai Creek.

3.2 Results

3.2.1 Water Temperature

The seasonal averages of water temperature during 1999 are presented in table 3.1. The minimum average level (21.17°C) was recorded during winter (January-March 1999), whereas the maximum average level (33.85°C) was obtained during

Table 3.1 *Seasonal average variations in water temperature (°C) along Dubai Creek during 1999*

Stations	Winter	Spring	Summer	Autumn
1	20.67	28.43	33.96	28.97
2	20.58	28.50	33.66	29.07
3	21.49	28.83	33.60	29.23
4	21.30	28.60	34.20	29.17
5	21.23	28.40	34.00	28.97
6	21.31	28.67	33.97	29.03
7	21.53	28.60	33.89	29.00
8	21.13	28.77	34.04	29.03
9	21.19	28.70	33.58	29.07
10	21.24	28.97	33.56	29.10
Average±S.D	21.17±0.31	28.65±0.18	33.85±0.23	29.06±0.08

summer (July-September 1999). Column wise difference in the temperature shows gradual decreasing trend from the surface to the bottom (Figure 3.1).

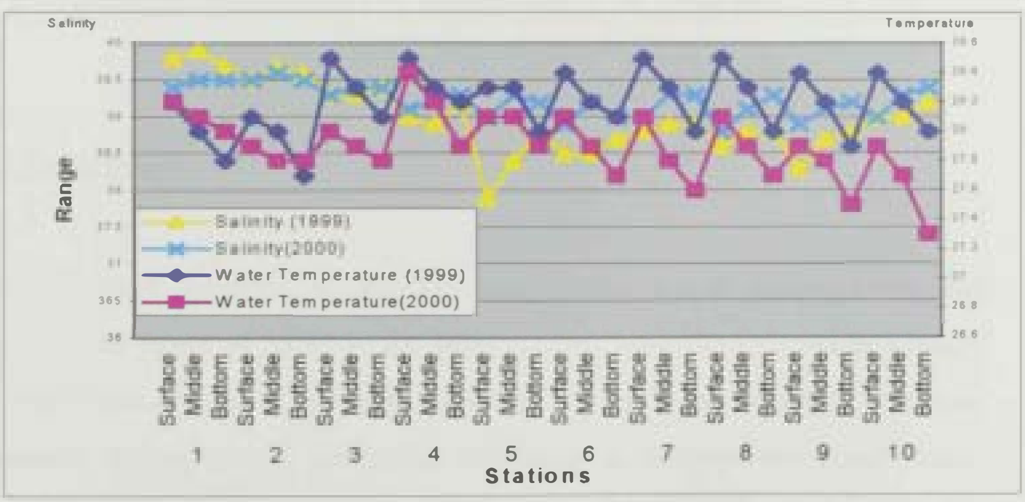


Figure 3.1 *Annual average variations in water temperature (°C) and salinity (‰) along Dubai Creek during 1999-2000*

Seasonal fluctuation in average temperature during 2000 varied in a range of 22.43 to 32.57 °C (Table 3.2). The minimum average level of temperature value was obtained during winter (January-March 2000), whereas the maximum average temperature was recorded during summer (July-September 2000). The temperature distribution during 2000 was almost comparable to 1999. Vertical fluctuations in the temperature were insignificant. The highest values were obtained at the surface as compared to the bottom (Table 3.2, Figure 3.1).

Table 3.2 *Seasonal average variations in water temperature (°C) along Dubai Creek during 2000*

Stations	Winter	Spring	Summer	Autumn
1	22.41	28.74	33.23	27.99
2	22.25	28.58	32.80	27.75
3	22.24	28.89	32.82	27.68
4	22.58	29.20	33.18	27.59
5	22.48	29.30	32.99	27.37
6	22.52	29.25	32.28	27.47
7	22.45	29.25	32.16	27.39
8	22.47	29.19	32.34	27.59
9	22.43	28.96	32.09	27.47
10	22.46	28.92	31.83	27.43
Average±S.D	22.43±0.11	29.03±0.25	32.57±0.49	27.57±0.19

3.2.2 Salinity

Seasonal average variation in salinity along Dubai Creek during 1999 was observed in the range of 38.47 to 39.30‰ (Table 3.3). The maximum average level was noticed during summer, whereas the minimum average level was encountered during spring. Vertical difference in salinity was insignificant, however there was slightly higher values at the bottom as compared to the surface (Figure 3.1).

Table 3.3 *Seasonal average variations in salinity (‰) along Dubai Creek during 1999*

Stations	Winter	Spring	Summer	Autumn
1	40.42	39.14	39.96	39.73
2	40.30	39.01	39.59	39.50
3	39.20	39.19	39.62	39.30
4	38.16	39.11	39.56	39.17
5	38.49	38.18	37.69	39.07
6	38.12	37.73	38.79	39.57
7	38.78	38.06	39.06	39.47
8	38.72	37.78	39.19	39.10
9	38.26	37.96	39.36	38.90
10	38.48	38.53	40.16	39.07
Average±S.D	38.89±0.84	38.47±0.60	39.30±0.70	39.29±0.27

The seasonal average fluctuations in the salinity along Dubai Creek during 2000 were observed in the range of 38.93 to 39.81‰ (Table 3.4). The minimum and maximum average levels were observed during autumn and summer respectively.

Table 3.4 *Seasonal average variations in salinity (‰) along Dubai Creek during 2000*

Stations	Winter	Spring	Summer	Autumn
1	39.52	39.42	39.62	39.30
2	39.53	39.34	39.95	39.31
3	39.38	39.27	39.77	39.09
4	39.31	38.77	39.86	38.93
5	38.77	39.03	39.97	38.87
6	38.71	39.13	39.73	38.83
7	39.13	39.13	39.82	38.73
8	39.06	38.70	39.67	38.58
9	38.84	38.92	39.65	38.68
10	39.01	39.05	40.01	39.01
Average±S.D	39.13±0.30	39.08±0.23	39.81±0.14	38.93±0.25

3.2.3 pH

In 1999, the seasonal average variation in pH values were in the range of 8.52 to 8.78 (Table 3.5). The average minimum (8.52) and maximum (8.78) levels were obtained during autumn and winter respectively. The pH levels at stations 1, 2, and 3 were generally lower than the level of pH obtained between the stations 4-10 (Figure 3.2).

Table 3.5 *Seasonal average variations in pH along Dubai Creek during 1999*

Stations	Winter	Spring	Summer	Autumn
1	8.32	8.31	8.29	8.39
2	8.41	8.50	8.33	8.44
3	8.37	8.68	8.34	8.46
4	8.81	8.87	8.47	8.63
5	8.96	8.89	8.59	8.67
6	9.01	8.87	8.59	8.73
7	8.99	8.87	8.60	8.74
8	8.94	8.68	8.60	8.77
9	8.91	8.77	8.64	8.73
10	9.06	8.62	8.75	8.68
Average±S.D	8.78±0.29	8.71±0.19	8.52±0.15	8.62±0.14

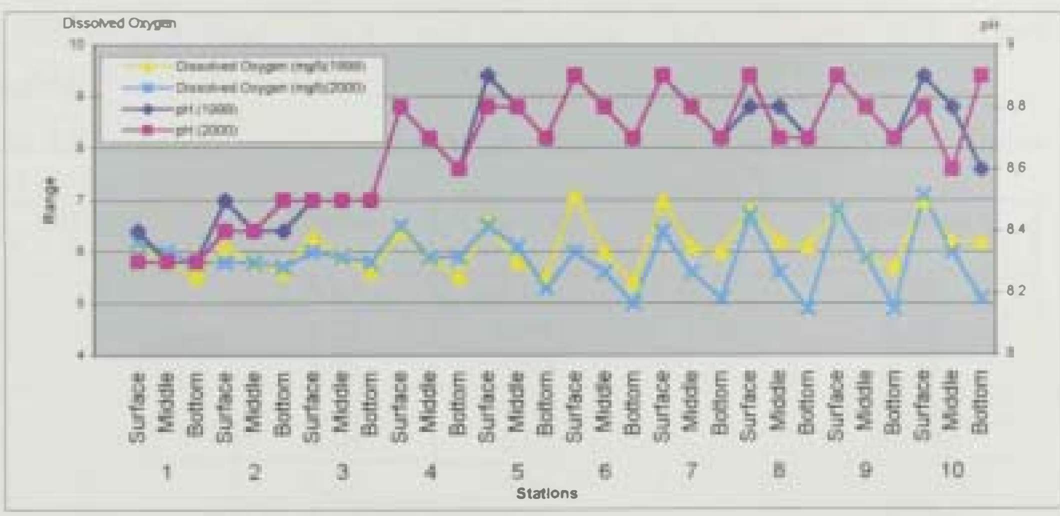


Figure 3.2 *Annual average variations in pH and dissolved oxygen (mg/ℓ) along Dubai Creek during 1999-2000*

The seasonal average levels of pH during 2000 were in the range of 8.74 to 8.76 (Table 3.6). The minimum and maximum average levels were obtained during summer and spring respectively. Column wise difference, pH values are higher at the surface as compared to the bottom (Figure 3.2).

Table 3.6 *Seasonal average variations in pH along Dubai Creek during 2000*

Stations	Winter	Spring	Summer	Autumn
1	8.32	8.31	8.29	8.36
2	8.41	8.50	8.33	8.42
3	8.37	8.66	8.35	8.50
4	8.80	8.89	8.50	8.63
5	8.86	8.99	8.58	8.67
6	8.88	8.87	8.60	8.68
7	8.83	8.94	8.58	8.73
8	8.87	8.77	8.60	8.77
9	8.80	9.01	8.67	8.72
10	8.90	8.64	8.91	8.68
Average±S.D	8.70±0.24	8.76±0.23	8.54±0.19	8.62±0.14

3.2.4 Dissolved Oxygen

The seasonal average levels of dissolved oxygen (DO) along Dubai Creek during 1999 were recorded in a wide range of 5.62 to 6.41 mg/ℓ(Table 3.7). The minimum and maximum average levels were observed during summer and winter respectively.

Table 3.7 *Seasonal average variations in dissolved oxygen (mg/ℓ) along Dubai Creek during 1999*

Stations	Winter	Spring	Summer	Autumn
1	6.03	6.01	5.17	6.02
2	6.02	5.98	5.29	5.79
3	6.50	5.99	5.31	5.70
4	6.32	6.00	5.37	6.01
5	6.64	6.07	5.22	6.29
6	6.27	6.56	5.30	6.55
7	6.73	6.37	5.94	6.34
8	6.74	6.33	6.08	6.28
9	6.27	6.03	6.23	6.01
10	6.60	6.41	6.32	6.46
Average±S.D	6.41±0.27	6.18±0.22	5.62±0.46	6.14±0.28

Vertical variations between the surface, middle, and the bottom layers were apparent particularly between stations 5-10 (Figure 3.2). The surface layer sustains higher DO levels as compared to the bottom layer.

The seasonal averages of DO varied from 5.53 to 6.36 mg/ℓ during 2000 (Table 3.8). The minimum and maximum average levels were noticed during winter and spring respectively.

Table 3.8 *Seasonal average variations in dissolved oxygen (mg/ℓ) along Dubai Creek during 2000*

Stations	Winter	Spring	Summer	Autumn
1	6.01	6.06	5.76	6.28
2	5.78	6.19	5.50	5.80
3	6.02	6.47	5.33	5.70
4	6.34	6.96	5.79	5.75
5	5.86	6.93	5.26	5.35
6	5.24	5.80	4.98	5.70
7	5.31	6.57	4.93	6.00
8	4.68	6.13	6.15	5.67
9	4.96	6.23	6.15	6.18
10	5.08	6.25	6.18	6.71
Average±S.D	5.53±0.55	6.36±0.37	5.60±0.48	5.91±0.39

3.2.5 Turbidity

The seasonal average fluctuation in the levels of turbidity along Dubai Creek during 1999 ranged between 0.9 to 3.1 NTU (Table 3.9). The minimum and maximum levels were obtained during autumn and spring respectively.

Table 3.9 *Seasonal average variations in turbidity (NTU) along Dubai Creek during 1999*

Stations	Winter	Spring	Summer	Autumn
1	2.50	2.00	0.50	0.50
2	2.50	2.00	1.00	1.00
3	2.50	2.50	1.50	0.50
4	3.00	2.50	1.50	1.00
5	3.00	5.00	1.50	1.00
6	3.00	3.50	1.50	1.00
7	3.00	2.50	1.50	1.00
8	3.00	4.00	1.50	1.00
9	3.00	3.50	1.50	1.00
10	3.00	3.50	1.50	1.00
Average±S.D	2.85±0.24	3.1±0.97	1.35±0.34	0.9±0.21

The distribution of seasonal averages of turbidity during 2000 ranged between 1.6-3.15 NTU (Table 3.10). The minimum and maximum average levels were observed during summer and autumn respectively.

Table 3.10 *Seasonal average variations in turbidity (NTU) along Dubai Creek during 2000*

Stations	Winter	Spring	Summer	Autumn
1	1.00	1.00	0.50	1.00
2	1.00	2.50	0.50	1.00
3	1.50	2.00	1.00	1.50
4	2.00	2.00	1.50	1.50
5	2.00	1.50	2.00	2.00
6	2.00	2.00	2.00	1.50
7	2.00	2.00	2.50	3.00
8	3.00	1.50	2.00	2.50
9	2.50	1.50	2.00	2.50
10	2.50	1.50	2.00	15.00
Average±S.D	1.95±0.64	1.75±0.42	1.6±0.70	3.15±4.22

The annual averages of turbidity levels are high between stations 4-10 as compared to stations 1-3 (Figures 3.3-3.4).

Generally, the turbidity values were comparatively lower between stations 1-3 during 1999 and 2000 (Figure 3.3 and 3.4).

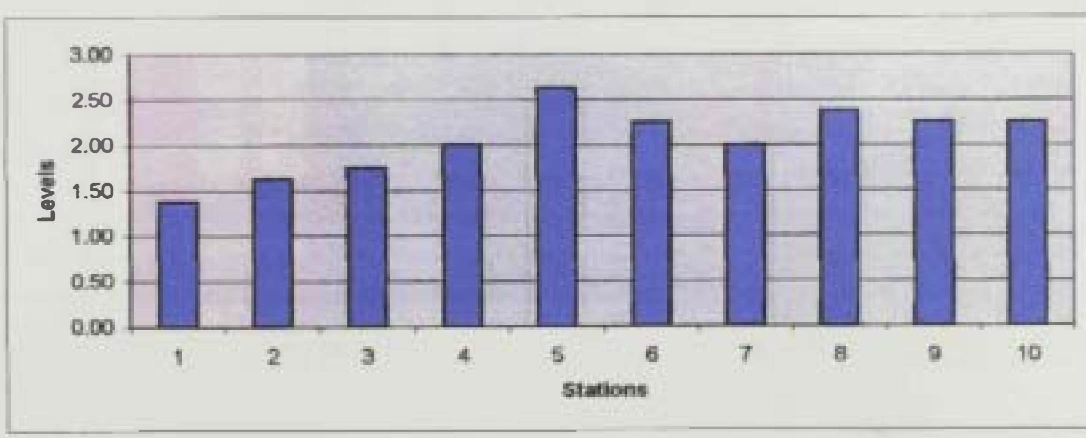


Figure 3.3 *Variation in turbidity (NTU) along Dubai Creek during 1999*

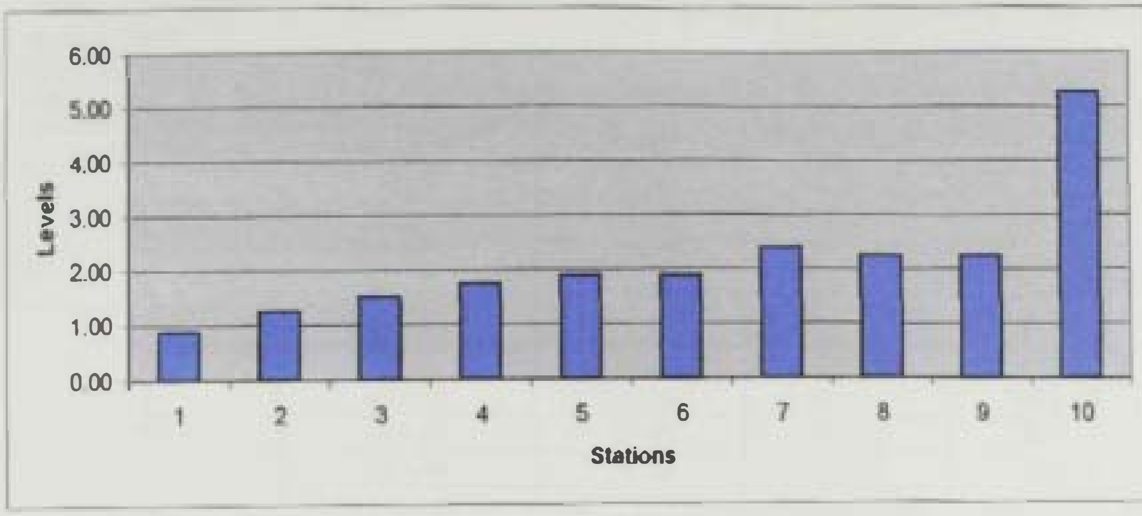


Figure 3.4 *Variations in turbidity (NTU) along Dubai Creek during 2000*

3.2.6 Total Nitrogen

In 1999, the seasonal average variations in total nitrogen levels were 56.93 to 150.0 μg-at/ℓ along Dubai Creek (Table 3.11). The minimum and maximum values were obtained during summer and winter.

Table 3.11 *Seasonal average variations in total nitrogen (μg-at/ℓ) along Dubai Creek during 1999*

Stations	Winter	Spring	Summer	Autumn
1	132.85	27.15	14.29	45.71
2	128.58	14.29	23.57	42.85
3	132.85	75.71	28.56	37.14
4	197.14	95.70	71.44	107.14
5	142.85	214.28	70.00	149.99
6	145.72	164.29	68.58	135.73
7	142.85	121.43	85.71	164.29
8	142.85	199.99	71.44	149.99
9	164.29	207.14	68.58	164.29
10	169.99	142.85	67.14	178.58
Average±S.D	150.00±21.20	126.28±72.50	56.93±24.80	117.57±55.60

The trend in seasonal averages of total nitrogen during 2000 along Dubai Creek was similar to 1999 (Table 3.12). However, the levels were higher in some stations 6 and 10. The minimum and maximum seasonal average levels were in the range of 55.14 to 165.14 µg-at/ℓ.

Table 3.12 *Seasonal average variations in total nitrogen (µg-at/ℓ) along Dubai Creek during 2000*

Stations	Winter	Spring	Summer	Autumn
1	52.85	25.01	10.72	16.43
2	44.29	28.56	16.43	13.57
3	87.86	29.28	26.43	61.44
4	117.86	128.58	37.86	105.01
5	124.29	71.44	85.71	207.86
6	142.85	78.58	92.85	353.58
7	126.42	100.00	50.00	137.14
8	497.15	70.72	60.00	206.42
9	124.29	71.44	100.00	203.57
10	167.86	78.58	71.44	346.44
Average±S.D	148.57±128.30	68.22±33.10	55.14±32.10	165.14±121.80

Total nitrogen level is in increasing trend beyond station 4 during 1999-2000 (Figures 3.5 and 3.6).

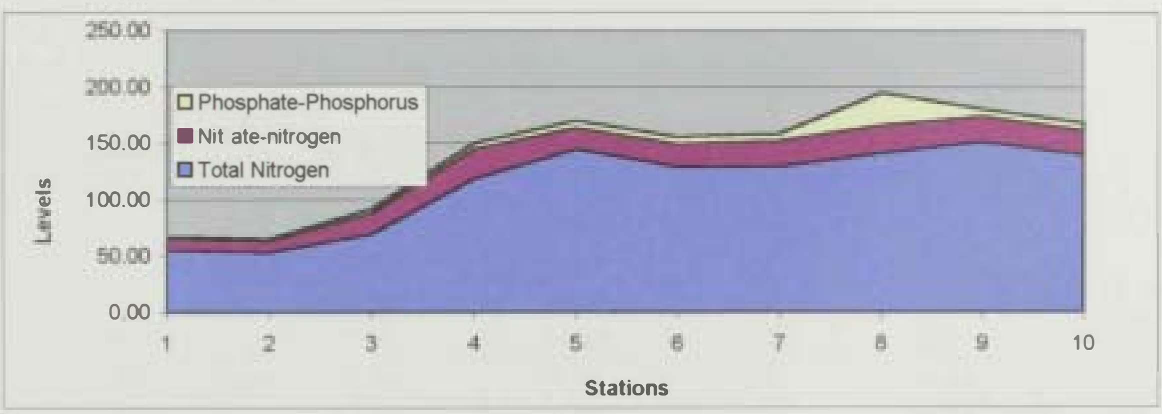


Figure 3.5 *Variation in nutrients (µg-at/ℓ) along Dubai Creek during 1999*

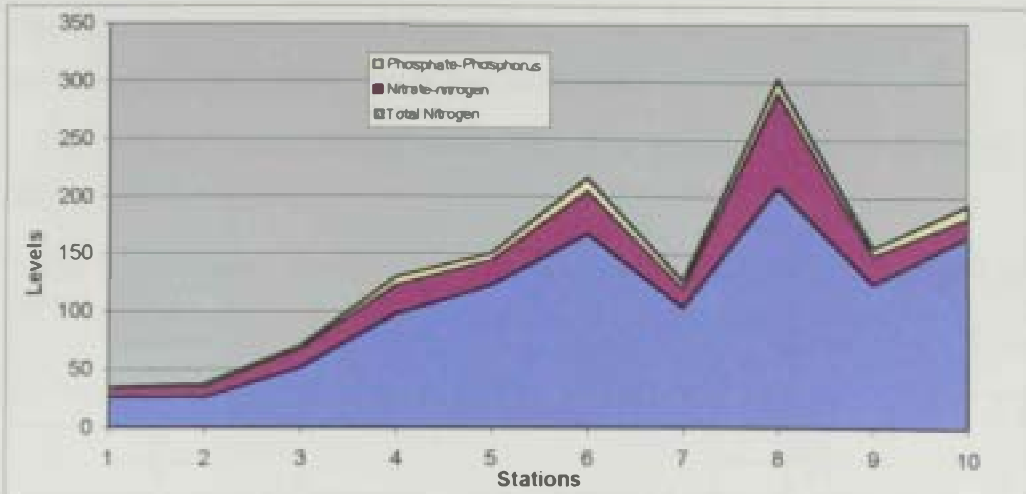


Figure 3.6 *Variation in nutrients (µg-at/ℓ) along Dubai Creek during 2000*

3.2.7 Nitrate-nitrogen

During 1999, the seasonal average variation of nitrate-nitrogen were in the range of 10.07 to 26.93 µg-at/ℓ (Table 3.13). The minimum and maximum average values were obtained during spring and autumn respectively.

Table 3.13 *Seasonal average variations in nitrate-nitrogen (µg-at/ℓ) along Dubai Creek during 1999*

Stations	Winter	Spring	Summer	Autumn
1	22.13	3.57	7.15	7.86
2	22.85	2.85	7.15	7.15
3	28.56	17.86	21.44	5.71
4	35.71	24.29	20.00	25.71
5	21.44	8.56	15.01	31.44
6	27.15	8.56	14.29	32.13
7	16.43	7.86	29.28	40.00
8	31.44	7.86	16.43	42.85
9	23.57	10.72	22.85	32.85
10	19.28	8.56	17.15	43.57
Average±S.D	24.86±5.8	10.07±6.5	17.07±6.8	26.93±14.8

In 2000, the seasonal average variation in the level of nitrate-nitrogen was observed ranged between 5.50 to 65.71 μg-at/ℓ (Table 3.14). The minimum and maximum average levels were observed during spring and winter respectively.

The levels of nitrate-nitrogen reaches high level between stations 4-10 during 1999 and 2000 (Figure 3.5-3.6).

Table 3.14 *Seasonal average variations in nitrate-nitrogen (μg-at/ℓ) along Dubai Creek during 2000*

Stations	Winter	Spring	Summer	Autumn
1	17.15	3.57	3.57	2.85
2	20.00	10.00	2.85	4.29
3	38.56	7.15	3.57	14.29
4	47.14	15.71	5.01	32.85
5	50.00	2.85	11.44	22.85
6	52.85	2.85	10.72	83.57
7	49.28	2.85	5.71	10.00
8	292.87	2.85	5.71	26.43
9	44.29	4.29	12.13	38.56
10	45.01	2.85	5.71	10.72
Average±S.D	65.71±80.80	5.50±4.30	6.64±3.50	24.64±23.90

3.2.8 Phosphate-phosphorus

In 1999, the data for phosphate-phosphorus along Dubai Creek were collected during autumn only. The recorded levels show a variation ranged between 0.97 to 22.66 μg-at/ℓ with an average level of 13.88 μg-at/ℓ (Table 3.15).

Table 3.15 *Seasonal average variations in phosphate-phosphorus (μg-at/ℓ) along Dubai Creek during 1999*

Stations	Winter	Spring	Summer	Autumn
1	-	-	-	0.97
2	-	-	-	0.97
3	-	-	-	0.65
4	-	-	-	14.89
5	-	-	-	19.42
6	-	-	-	19.42
7	-	-	-	21.04
8	-	-	-	21.04
9	-	-	-	17.80
10	-	-	-	22.66
Average±S.D	-	-	-	13.88±9.22

(-) indicates no data

The seasonal average fluctuation of phosphate-phosphorus during 2000 are in the range of 3.17 to 12.36 µg-at/ℓ (Table 3.16). The seasonal minimum and maximum average levels are obtained during summer and autumn respectively.

Table 3.16 *Seasonal average variations in phosphate-phosphorus (µg-at/ℓ) along Dubai Creek during 2000.*

Stations	Winter	Spring	Summer	Autumn
1	1.94	0.67	0.67	3.33
2	2.27	2.00	0.67	3.33
3	4.21	3.33	1.67	4.00
4	5.18	8.33	3.33	12.67
5	6.15	5.33	4.67	10.00
6	6.47	5.67	4.67	31.00
7	6.15	5.67	4.00	11.00
8	29.13	5.67	4.33	11.00
9	6.47	5.67	4.67	11.67
10	6.15	5.00	4.00	29.33
Average±S.D	7.41±7.82	4.60±2.12	3.17±1.59	12.36±9.58

As with other nutrients (total nitrogen, and nitrate-nitrogen), phosphate-phosphorus shows an increasing trend beyond station 4 (Figure 3.6).

3.3 Discussion

Dubai Creek is located within the North-Temperate tropical margin, a region that encompasses most of the Earth deserts. Generally, the temperature variation in the tropical region is limited. The observed range of temperature (20.58-33.85°C) in Dubai Creek during the present study is well comparable with the earlier records of temperature in Dubai Creek (Abu-Hilal and Adam 1995, Dubai Municipality, 2000b), and the temperature records of the ROPME Sea Area Members States (ROPME, 2000).

pH results show that the Creek is alkaline with an annual average variation of 8.4 to 8.7. Obviously these values are comparatively higher than the values obtained from the closest studied area of Abu Dhabi Creek (Abu-Hilal and Adam, 1995) and the United Arab Emirates waters (Shriadah and Al-Ghais, 1999); however they are well comparable with the earlier records for Dubai Creek (Abu-Hilal and Adam, 1995; Dubai Municipality, 2000b) as well as the values recorded during studies on eutrophication conducted by Mustafa *et al.*, (2001). pH values are low in the downstream region (stations 1-3) as compared to the upstream region (stations 4-10). In most of the cases, the differences in pH values between the surface, middle and bottom layers of the downstream region (stations 1-3) are almost similar to a well-mixed body of water (Halcrows, 1992). The insignificant columnwise differences in the pH values is attributed to the shallowness and vertical turbulences in the Creeks (Shriadah and Al-Ghais, 1999). Vertical stratification in the pH is evident in the upstream region. Higher values at the surface layer are due to high rate of photosynthesis which leads to the consumption of carbon dioxide; whereas the lower values at the bottom are mainly attributed to the decomposition of organic matter which results in carbon dioxide generation. Combination of factors such as photosynthetic activity, dissolved oxygen concentration, disposal of sewage wastewater and decomposition of organic matter in the creek waters are factors controlling the pH in the Creeks water of the United Arab Emirates (Shriadah and Al-Ghais, 1999).

The enhanced levels of pH along the upstream region show association with anthropogenic freshwater releases identified by the negative correlation of pH versus salinity ($r = -0.78$, $p<0.05$), this reflects the fact that the pH increases where the system receives freshwater influx (Figure 3.7). Abu-Hilal and Adam (1995) observed the same trend of distribution. They mentioned that Dubai Creek water is receiving anthropogenic inputs from outfalls located on the banks of the Creek.

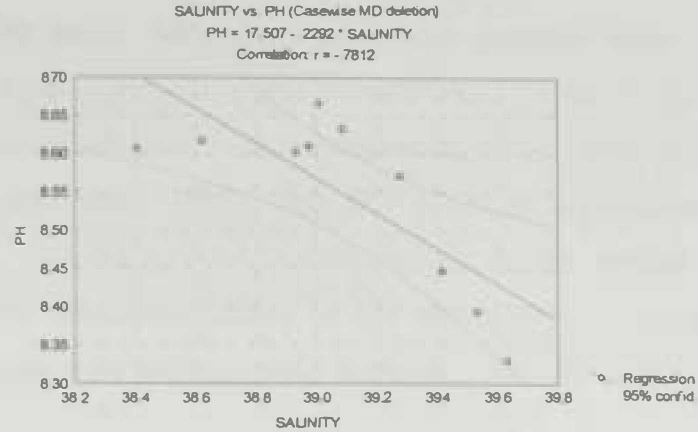


Figure 3.7 *Scatter Plot of salinity vs. pH showing a negative correlation*

The results indicate wide and significant temporal differences within the study area. The exceptionally high pH values (>9) along Dubai Creek are indicative of high primary productivity, which fully utilizes carbon dioxide. Such results of high pH levels associated with high primary productivity are also observed in Bombay coastal environment (Mustafa, 1995)

The seasonal pH variations are highest during the winter (8.74) and spring (8.73) as compared to the autumn (8.62) and summer (8.53). Higher pH levels during winter are mainly associated with high levels of chlorophyll *a* (Dubai Municipality 2000b), which as a result of photosynthesis increases the dissolved oxygen levels, whereas the lower pH values observed during summer are due to the oxidation of organic matter (Shriadah and Al Ghais, 1999).

Dissolved Oxygen (DO) content in an aquatic system is an essential influencing factor for aquatic life. The available DO is derived from the atmosphere and photosynthesis. Organic matter oxidation contributes to the depletion of oxygen in the water body. Changing balance between the oxygen supply and consumption leads to a characteristics DO profile. Therefore, under aerobic conditions the oxygen content is the most suitable measure for the state of waterbody.

In this study, DO shows wide fluctuations with generally higher levels at the upstream (6.1 mg/ℓ) as compared to the downstream (5.9 mg/ℓ) regions of Dubai Creek. The observed levels of DO are corresponding to the earlier records of Dubai Creek (Abu-Hilal and Adam, 1995). High DO values at the upstream region are usually associated with high photosynthetic activity at the surface water. The respective direct and inverse correlation of DO versus salinity ($r = -0.64$, $p<0.05$) testifies its association with anthropogenic freshwater releases in the Creek (Figure 3.8).

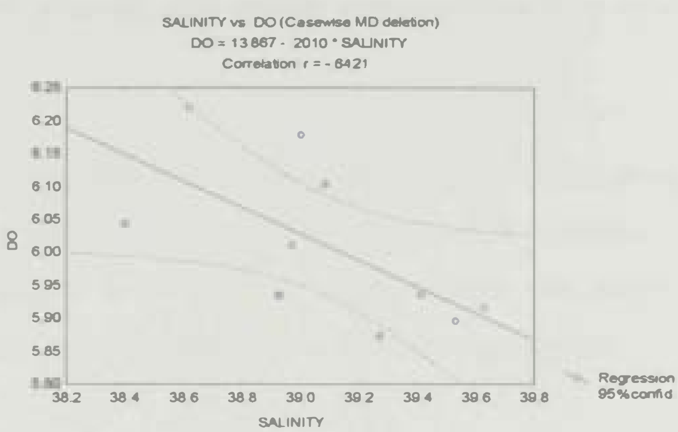


Figure 3.8 *Scatter Plot of salinity vs. DO showing a negative correlation*

Dubai Creek exhibits significant differences in vertical distribution of dissolved oxygen at the surface, middle, and bottom layers in the upstream region (Figure3.1). The low value at the bottom as compared to the surface is expected due to sediment respiration and chemical reactions, whereas the high dissolved oxygen values at the surface is due to air diffusion at the air-water interface, as well as agitation, and photosynthetic activity. The less well-mixed water in the upstream region indicates significant vertical stratification.

Seasonally, dissolved oxygen values are higher during the winter (5.9 mg/ℓ) as compared to the summer (5.6 mg/ℓ) seasons. Increasing DO values during winter is due to high solubility of oxygen in decreasing water temperature and increasing turbulence, while the falling DO values during summer is attributed to higher water temperature, therefore, increasing the rate of organic matter decomposition in the coastal and creeks waters of United Arab Emirates (Shriadah and Al-Ghais, 1999).

Salinity levels recorded during this study in Dubai Creek are higher than the oceanic waters (~35 ‰), but well comparable with the typical salinity regime of the Arabian Gulf. Usually, the Arabian Gulf are characterized by shallow depth and extreme air temperature, high evaporation rates, and restricted circulation of the Gulf water with the Arabian Sea through Straits of Hormuz (Hunter, 1982). The resulting offshore environment is harsh, with salinity extremes exceeding other areas of the world.

The horizontal distributions of the salinity are more prominent along Dubai Creek. The downstream region is highly saline as compared to the upstream. In the upstream region, between stations 5 to 10, low salinity levels are associated with the anthropogenic freshwater inputs, mainly from the following sources:-

- Outfall No. 18 - Treated effluent discharges
- Outfall No. 20 – Groundwater dewatering
- Outfall No. 16 - Stormwater discharge
- Outfall No. 24 - Stormwater discharge

The vertical distribution of salinity indicates slightly higher values at the bottom as compared to the surface along the upstream region. Salinity depth profile is developed due to low-mixing of the water. In general, the salinity is mainly influenced by the quality and quantity of discharges along the banks of the Creek rather than prevailing regime in the Arabian Gulf (Grasshoff, 1976).

The significant negative correlation of salinity ($p<0.05$) versus turbidity ($r = -0.76$), total nitrogen ($r = -0.79$), nitrate-nitrogen ($r = -0.63$), and phosphate-phosphorus ($r = -0.78$) in the water quality parameters indicate that pollutants in the Creek originate from the freshwater discharges (Figure 3.9).

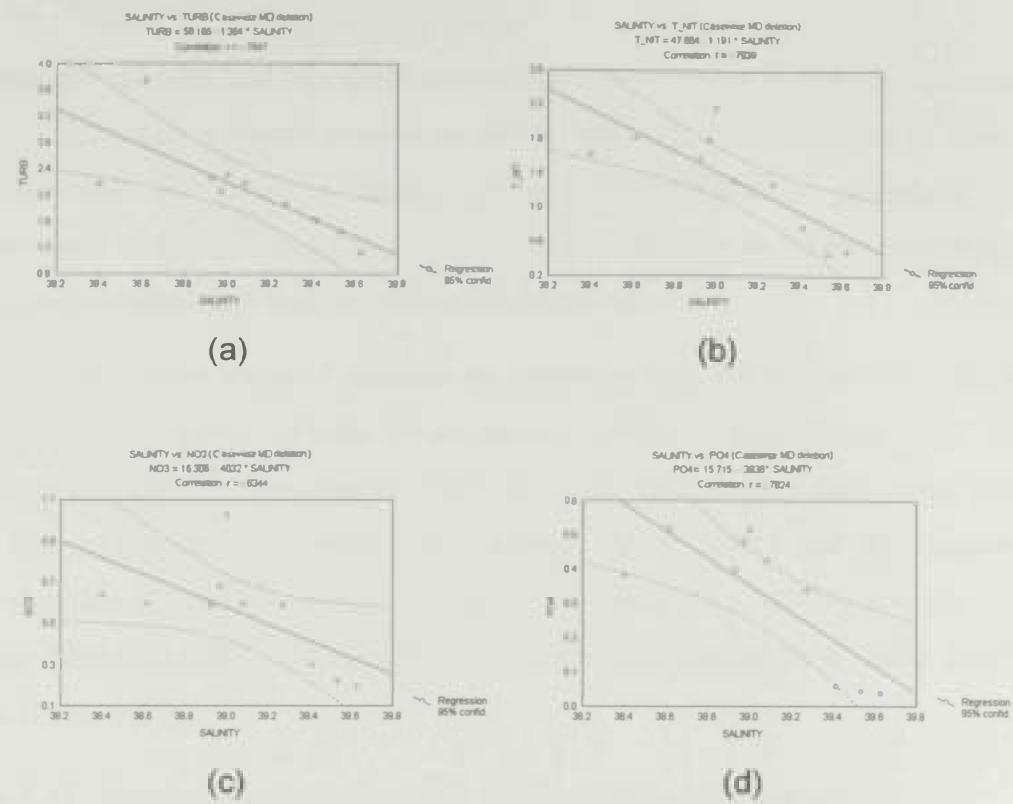


Figure 3.9 *Scatter Plots of salinity vs. turbidity (a), total nitrogen (b), nitrate-nitrogen (c) and phosphate-phosphorus (d) showing negative correlations*

The salinity profile along the downstream (39.5‰) and the upstream (38.9‰) regions are within the range recorded earlier in Dubai Creek by Abu-Hilal and Adam (1995), however it is lower than the values reported by Basson *et al.*, (1977), and Abu-Hilal *et al.*, (1990) from the Gulf of Oman; and higher than the values reported by Abu-Hilal and Adam (1995) for Abu Dhabi Creek in the Arabian Gulf.

The average turbidity of Dubai Creek recorded during this study is slightly higher than the average turbidity recorded for the Dubai offshore region (Dubai Municipality, 2000b). High turbidity is associated with high planktonic growth and eutrophication, which has reached up to 15 NTU at station 10 during autumn 2000. Generally, the upstream is highly turbid as compared to the downstream regions. The reasons being factors such as poor flushing, low mixing rate and high planktonic growth. Such levels are reported in earlier study associated with the problem of eutrophication in the upstream region of Dubai Creek conducted by Dubai Municipality, (1997b).

Dissolved nitrogen and phosphorus compounds are present in low concentrations in seawaters. Nitrogen is mainly present as nitrate with low concentrations of nitrite and ammonia, while the major inorganic species of phosphorus is phosphate. High concentrations of these nutirents in water however can lead to excessive growth of algae resulting in eutrophication in extreme cases (NIO, 1992).

Overall, the present levels of nutrients are extremely high but comparable with earlier studies in Dubai Creek (Dubai Municipality, 1997b; Dubai Municipality, 2000b; Mustafa *et al.*, 2001). The observed high levels are much higher than Dubai and Abu Dhabi Creeks reported in 1995 (Abu-Hilal and Adam, 1995) and also significantly higher than Kuwait, Saudi Arabia, and Qatar (Dorgham *et al.,* 1987), and the U.A.E. coastline (Shriadah and Al-Ghais, 1999). These levels in Dubai Creek have fluctuating pattern (Table 3.17).

Table 3.17 *Nutrients contents (μg-at/ℓ) of the Arabian Gulf waters*

Area	**Nitrate-nitrogen**	**Phosphate-phosphorus**	**Reference**
Dubai Creek 1989-90	0.50-23.79	0.80-28.82	*Abu-Hilal and Adam (1995)*
Abu Dhabi Creek 1989-90	0.08-18.72	0.02-4.53	*Abu-Hilal and Adam (1995)*
Kuwait	0.16-0.38	0.14-0.18	*Dorgham et al., (1987)*
Saudi Arabia	0.09-1.27	0.0-0.34	*Dorgham et al., (1987)*
Qatar	0.30-0.38	0.20-0.88	*Dorgham et al., (1987)*
Dubai Creek Mean±S.D	2.85-43.57 (19.73±5.62)	0.97-22.66 (13.88±9.22)	*Present Study(1999)*
Dubai Creek Mean±S.D	2.85-292.87 (25.62±21.64)	0.65-30.10 (6.89±3.85)	*Present Study(2000)*

Sharp changes exists between the downstream and upstream regions, the latter showing high levels. The principal reason is attributed to the inputs from sewage treatment plant- despite tertiary treatment- containing high level of nitrate and phosphate. Furthermore, the mixing and dilution processes in this region are very poor (Halcrows, 1992).

Although the variations among the stations are irregular but a remarkable difference exists between the downstream and upstream regions. Comparison between the nutrients in the downstream and upstream regions during present study indicate anthropogenic releases in the upstream region from land-based sources (Table 3.18).

Table 3.18 *ratios of nutrients between downstream, and upstream regions of Dubai Creek*

Nutrients	Downstream region	Upstream region
Total nitrogen (μg-at/ℓ)	1	2.8
Nitrate-nitrogen (μg-at/ℓ)	1	3.5
Phosphate-phosphorus (μg-at/ℓ)	1	8.8

The atomic ratio of nitrogen to phosphorus (N: P) in this study is 29: 1 in the downstream, and 9.7: 1 in the upstream region (Table 3.19). The existing N: P ratio in the upstream region is closer to the nearby areas of Ras Al-Khaima (9.8:1), Abu Dhabi (9.5:1) and Umm Al-Quwain (8.9:1) as reported by Shriadha and Al-Ghais (1999).

Table 3.19 *Atomic ratios of nitrogen and phosphorous (N: P) along downstream, and upstream regions of Dubai Creek*

Parameters	Downstream region	Upstream region
Total nitrogen (μg-at/ℓ)	42.9	121.4
Phosphate-phosphorus (μg-at/ℓ)	1.6	14.2
N: P ratio	1 : 27	1 : 8.5

N: P ratio along upstream region of Dubai Creek is lower than the global oceanic ratio of 16:1 (Redfield, 1934) whereas, the N: P ratio along the downstream region is significantly higher than 16:1. Algal production is correlated to the levels of nitrogen (N) and phosphorus (P) in the water. Above a 15:1-16:1 N: P ratio in an estuarine or coastal area, the system will likely experience an algal bloom, the severity of which will be in relation to the excess phosphorus available (Schindler, 1978; Jaworski, 1981). In those systems, where N: P are below 10:1, nitrogen is limiting nutrient and the estuarine or coastal system will experience algal bloom if excessive nitrogen becomes available (Jaworski, 1981). Typically, N: P ratio above 16:1 in the water column of the estuarine or coastal system is generally non-eutrophic, which reveals algal bloom in the presence of excessive phosphorus; while the N: P ratio below 16:1 is indicative of nitrogen as the limiting nutrient, which generates the algal bloom if nitrogen becomes available (Jaworski, 1981). Generally, a phosphate concentration of 0.3 μg-at/ℓ will support plankton growth, while concentration 1.0-3.2 μg-at/ℓ phosphate will likely trigger blooms (USEPA, 1986; Dunne and Leopard, 1978). A high availability of phosphate does not always indicate continued production because the system may become nitrogen limited. Phytoplanktons utilize N and P in ratios of 3 to 30 by atoms; the ratio of above 16 is associated with optimal growth conditions (Edward 1992).

The relatively lower level of phosphate and a high ratio of N: P indicates a non-eutrophic condition in the downstream region of Dubai Creek The presence of excess nitrogen in addition to low N: P ratio confirms the eutrophic conditions in the upstream region. The principal reasons for high nitrogen levels are associated with the treated wastewater discharges into this region. According to Shriadah and Al-Ghais, 1999, the ratio of below 10 is due to the effect of disposal of either partially or improperly treated wastewater in the coastal water of the United Arab Emirates. Low N: P ratio in the upstream region of Dubai Creek adversely affects the water quality and ecosystem as manifested by the weakening immune system of the fish due to infection by bacterial disease (Hemorrhagic Septicemia) by member of genera *Aeromonas* and *Vibrio,* that causes mass fish mortality (Dubai Municipality, 1995a). The negative impact of eutrophication on aesthetic value of Dubai Creek is remarkable (Dubai Municipality 1997b) and an unappealing colours by the dense algal bloom during different seasons (Dubai Municipality, 1997c) are also evident in the upstream region of Dubai Creek.

Low levels of nutrients in the downstream region support high biological diversity and healthy ecosystem, whereas the impacts of high nutrients at the upstream region indicate very poor diversity at different trophic levels (Dubai Municipality 1997b). The recommended level of nitrogen in a healthy coastal system to avoid algal bloom is 6.7 to 67.5 (µg-at/ℓ), while the phosphorus concentration is 0.3 to 3.2 (µg-at/ℓ). Higher concentration of both leads to less diversity (NOAA/EPA, 1988).

Nutrients positive correlation with DO indicates association with oxygen contributing to eutrophic conditions in the water body (Figure 3.10). Such results are also previously reported and reflect the problem of eutrophication in the lagoon of Dubai Creek (Mustafa *et al.*, 2001). Factors causing these changes include intermittent wastewater discharges from various outfalls.

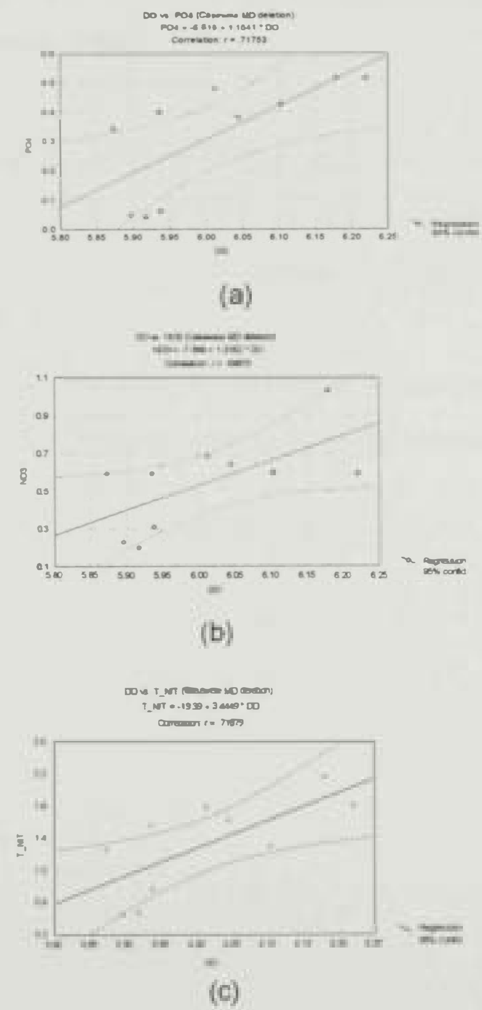


Figure 3.10 *Scatter Plots of DO vs. nutrients: phosphate-phosphorus (a), nitrate-nitrogen (b), and total nitrogen (c), showing positive correlations*

Overall, this investigation proves the following findings on the water quality parameters: -

1. Dubai Creek exhibits eutrophic conditions in the upstream region, while the downstream region indicates a healthy non-eutrophic condition.

2. High levels of nutrients along the upstream region of Dubai Creek are derived from the land-based sources.

3. The negative correlations of salinity versus water quality parameters indicate that the variations in these parameters are mainly associated with freshwater influx.

4. Total nitrogen, nitrate-nitrogen and phosphate-phosphorus levels are respectively 2.8, 3.5 and 8.8 times higher in the upstream as compared to the levels observed in the downstream regions.

5. High nutrients loads in the upstream region have severe adverse impact on the fisheries potential, biodiversity and aesthetic value of the Creek.

***

CHAPTER IV

Results and Discussion

SEDIMENT QUALITY

Sediment Quality

4.1 Introduction

Pollution of the marine environment is a continuing global concern. Sediments are considered as an intensely important component for the assessment of marine environmental pollution. Estuarine and coastal marine sediments are considered as a sink for many materials transported from land. Many substances that occur naturally, such as trace metals, hydrocarbons and nutrients, may be mobilized as a result of natural processes as well as man-made activities and these may become enriched in the Creek and coastal sediments (Windom *et al.*, 1989).

Water quality measurements provide a short-term integrator of pollutant inputs and are more susceptible to contamination during sampling and analysis. A special difficulty arises from contaminants that is not readily soluble but becomes rapidly fixed to particulate matter in the receiving water body. This is particularly applied in to heavy metals. Even close to the point of input, the metal content in water decreases to its normal level making detection difficult. The establishment of metal levels in sediments can, therefore, play a key role in detecting sources of pollution in aquatic systems (Förstner and Wittman, 1981).

Researchers provide valuable data on the concentration of trace metals in the sediments from various part of the world such as Brooks et *al.*, (1967) from Southern California USA; Aller *et al.*, (1984) from China Sea, Kouadio and Treffy, (1986) from West Africa, and El-Sammak and Aboul-Kassim, (1999) from Mediterranean Sea.

Substantial amount of information on the sediments quality of the Arabian Gulf is available. The first report on the preliminary investigations on trace metals in Kuwait sediments has been published by Samhan, *et. al.*, (1979). Further investigations have been documented by various researchers in the sediments of the: Arabian Gulf (Al-Hashimi and Salman, 1985; Abayachi and Douabul, 1986; Basaham and El-Sayed, 1997); Kuwait (Anderlini *et al.*, 1986); and the Red Sea (Abu-Hilal and Bardan, 1990; Basaham, 1997). Critical review of selected heavy metals and chlorinated hydrocarbons in the sediments from the Arabian Gulf along with the levels of Atlantic region, Baltic Sea, Mediterranean region, and Indian Ocean has been systematically documented Fowler (1990). The levels of trace metals in the Arabian Gulf sediments after the Gulf war have been studied by Fowler *et al.*, (1993). Study on chemical characterization of the sediments from the Gulf area after the oil spill of 1991 has been reported by Al-Arfaj and Alam, (1993); while the another study on sedimentological characteristcis of the bottom sediments has been documented by Al-Ghadban *et al.*, (1996). Study of the core samples metal content as pollution indicator as well as implication for the effect and fate of Kuwait oil slick has also been conducted on the Arabian Gulf in 1992 by Al-Abdali *et al.*, (1996). The recent studies on heavy metals from the Arabian Gulf, U.A.E. coast has been presented by Shriadah (1999) and El-Sammak (2000).

A study with respect to total mercury in the Arabian Gulf sediment has been conducted by Kureishy and Ahmed, (1994); while Dahab and Al-Madfa, (1997) studied the chromium distribution in the waters and sediments of Qatari peninsula.

The information on sediment characteristics along Dubai Creek with respect to nutrients and heavy metals are still limited. The first data on heavy metals, organic carbon, and grain size analysis in the sediments from four stations in Dubai Creek have been presented by Abu-Hilal and Khordagui, (1992). The same study also covers the levels of heavy metals from other Emirates (Abu Dhabi, Sharjah, Ajman, Umm Al Qaiwain, Ras Al-Khaimah and Fujairah). In 1997 a study with respect to sediments in Dubai Creek has shown amassed levels of nutrients, hydrocarbons, and heavy metals in the uppermost layer of the sediment in the lagoon of Dubai Creek (Dubai Municipality 1997b). The sediment quality data with respect to nutrients, heavy metals, and hydrocarbons has been documented in the annual report of Dubai Municipality's EPSS (Dubai Municipality 2000b). The geochemical association along Ras Al-Khaimah sediments was examined by El-Sammak (2000). Very recent study of Al-Qubaisi (2001) covers the coastal and Creek sediments along Abu Dhabi, Dubai and Sharjah for their concentration of heavy metals, organic carbons and minerological composition. El-Sammak (2001) provided concentration of heavy metals in the sediments of Dubai Creek.

In the present investigation, a systematic survey on sediment quality with respect to heavy metals from 10 locations in Dubai Creek was considered for interpretation and assessment.

4.2 Results

Table 4.1 demonstrates an overall results obtained for various sediments characteristics parameters (moisture content, organic carbon, sand and mud).

Table 4.1 *Variations in Moisture Content, Organic Carbon, and sediment Texture in the surface sediments along Dubai Creek during 2000*

Stations	Moisture Content (%)	Organic Carbon (%)	Mud (%)	Sand (%)
1	18.2	0.3	0.8	99.2
2	24.2	1.0	1.8	98.2
3	22.4	2.0	1.0	99.0
4	23.6	2.4	0.6	99.4
5	50.6	3.7	9.3	90.7
6	62.1	5.8	7.2	92.8
7	64.0	2.5	9.7	90.3
8	33.1	2.9	5.4	94.6
9	56.9	4.0	2.3	97.7
10	45.0	2.0	5.5	94.5
Average±S.D	40.0± 17.8	2.7±1.6	4.4± 3.5	95.6± 3.5

4.2.1 Moisture Content

Moisture contents in the surface sediments vary in a range of 18.2% at station 1 to 64.0% at station 7 with an overall average of 40% (Figure 4.1).

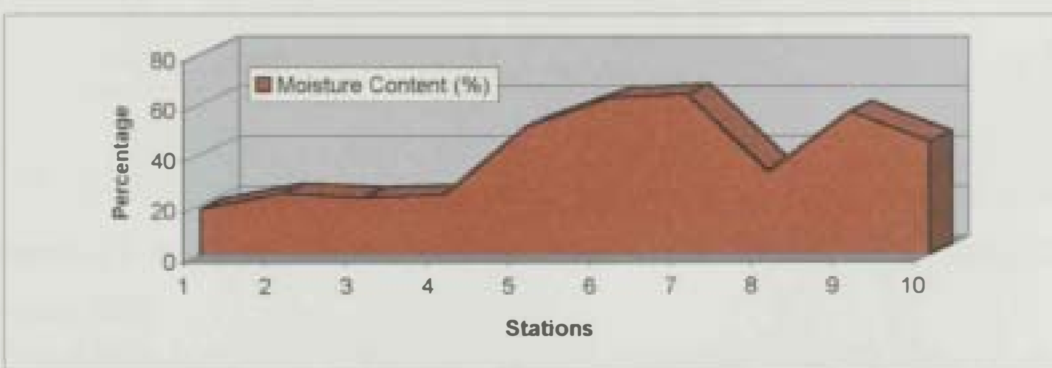


Figure 4.1 *Moisture Content (%) in the surface sediments along Dubai Creek during 2000*

4.2.2 Organic Carbon

Organic Carbon levels in the sediments along Dubai Creek are in a range of 0.3 to 5.8% at station 1 and 6 respectively with an average value of 2.7%. (Figure 4.2).

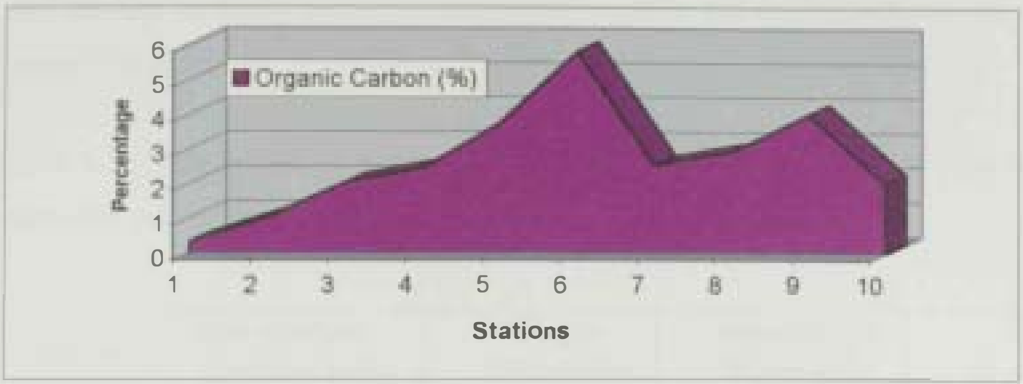


Figure 4.2 *Organic Carbon (%) in the surface sediments along Dubai Creek during 2000*

4.2.3 Texture analysis (Mud and Sand)

Mud contents fluctuate between 0.6 and 9.7 % with an overall average of 4.4 % (Table 4.1). The minimum and maximum contents are observed at station 4 and station 7 respectively (Figure 4.3).

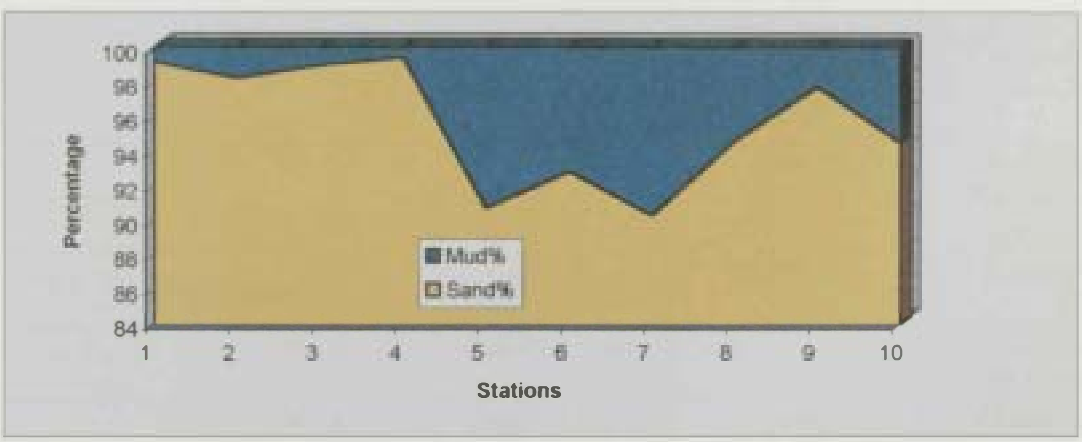


Figure 4.3 *Percentage of mud and sand in the surface sediments along Dubai Creek during 2000*

Sand along Dubai Creek fluctuates between a minimum of 90.3% and maximum of 99.4% with an overall average of 95.6% (Table 4.1). The minimum and maximum percentages of sand are noticed at stations 7 and 3 respectively (Figure 4.3).

4.2.4 Mineralogy

The results of core sediment mineralogy obtained from different layers between station 4 and 10 are given in Table 4.2. In general, the result of major minerals show that the top layers of all the stations contain calcite and quartz, whereas the bottom layers contain calcite.

Table 4.2 *Distribution of minor, major and subordinate minerals from the subsurface sediments along Dubai Creek during 2000*

Station	Sub-surface Fraction (cm)	Major Mineral(s)	Subordinate Mineral (s)	Minor Mineral (s)
4	0 - 4	Calcite, Quartz	-	Dolomite, Plagioclase, Aragonite
	4 - 8	Calcite, Quartz	-	Dolomite, Plagioclase, Aragonite
	8 - 12	Calcite	Quartz	Plagioclase, Dolomite
	12 – 16	Calcite, Quartz, Plagioclases	-	Aragonite, Dolomite
5	0 - 4	Calcite, Quartz	-	Plagioclase, Dolomite
	4 - 8	Calcite, Quartz	-	Plagioclase, Dolomite
	8 - 12	Calcite	Quartz	Aragonite, Plagioclase, Aragonite
	12 - 16	Calcite	Plagioclase, Quartz	Dolomite
6	0 - 4	Calcite, Quartz	-	Aragonite, Dolomite
	4 - 8	Calcite, Quartz	Quartz	Dolomite, Aragonite, Plagioclases
	8 - 12	Calcite, Quartz	Plagioclase	Plagioclase, Dolomite
	12 – 16	Calcite, Quartz, Plagioclases	-	Dolomite

Table 4.2 Continued....

Station	Sub-surface Fraction (cm)	Major Mineral(s)	Subordinate Mineral (s)	Minor Mineral (s)
7	0 - 4	Calcite, Quartz	Dolomite, Plagioclases	-
	4 - 8	Calcite, Quartz	Dolomite, Plagioclase	-
	8 - 12	Calcite, Quartz, Plagioclases	-	
8	4 - 8	Calcite, Quartz	Plagioclase, Dolomite	-
	8 - 12	Calcite, Quartz	-	Plagioclase, Dolomite, Aragonite
	12 - 16	Calcite, Gypsum Quartz	-	Dolomite
9	0 - 4	Calcite	Quartz	Dolomite, Aragonite, Plagioclase
	4 - 8	Calcite	Quartz	Plagioclase, Dolomite
	8 - 12	Calcite, Quartz	-	Dolomite, Plagioclase
10	0 – 4	Calcite, Quartz	Quartz, Aragonite	Plagioclase, Dolomite
	8 - 12	Calcite, Quartz	-	Dolomite, Aragonite Plagioclase
	12 - 16	Calcite, Quartz	-	Plagioclase, Dolomite

Among the minor minerals, aragonite, dolomite, and plagioclase feldspar are distributed along the sediment column (Table 4.2).

4.2.5 Heavy Metals

Tables 4.3-4.4 represent results obtained for levels of heavy metals in Dubai Creek during 1999 and 2000 respectively; whereas table 4.5 exhibits the range and average values obtained during1999-2000.

Table 4.3 *Levels of heavy metals (ppm) in the surface sediments along Dubai Creek during 1999*

Parameters / Stations	Copper	Nickel	Lead	Zinc	Chromium
1	5.2	20	38.9	10.4	20
2	6.5	20	30.1	18.3	20
3	5.4	20	42.2	25.8	20
4	14.2	20	42.6	55.6	20
5	28.9	21	70.9	121	49.9
6	15.9	20	43.6	43.6	27.8
7	31.9	20	91.6	130	69
8	26.2	20	76.1	69	53.8
9	157	24.6	89.5	467	44.1
10	45.2	24.5	98.2	133	82.7

Table 4.4 *Average levels of heavy metals (ppm) in the surface sediments along Dubai Creek during 2000*

Parameters / Stations	Copper	Nickel	Lead	Zinc	Chromium
1	6.6	35.0	58.2	7.9	40.0
2	8.0	35.0	59.8	12.9	40.0
3	8.4	35.0	62.9	24.3	40.0
4	17.4	35.0	40.0	68.9	40.0
5	56.9	35.0	42.9	233.5	42.3
6	19.5	35.0	40.0	74.2	44.0
7	35.2	35.0	42.6	183.6	51.9
8	11.9	35.0	40.0	37.3	55.0
9	228.6	63.5	59.2	776.0	54.9
10	29.5	41.1	40.9	132.3	63.4

Table 4.5 *Ranges and averages of heavy metals (ppm) along Dubai Creek during 1999-2000*

Range	Copper	Nickel	Lead	Zinc	Chromium
Minimum	5.2	20	30.1	7.9	20
Maximum	228.6	63.5	98.2	776.0	82.7
Average± S.D	37.9±56	29.7±11	55.5±20.1	131.2±185.5	43.9±17.1

4.2.5.1 Copper

There is a wide variation in the levels of copper at the surface sediments of Dubai Creek. The obtained levels show a variation of 5.2 to 228.6 ppm with a mean value of 37.9 ppm (Figure 4.4). The minimum and maximum levels were observed at stations 1 and 9 during 1999 and 2000 respectively.

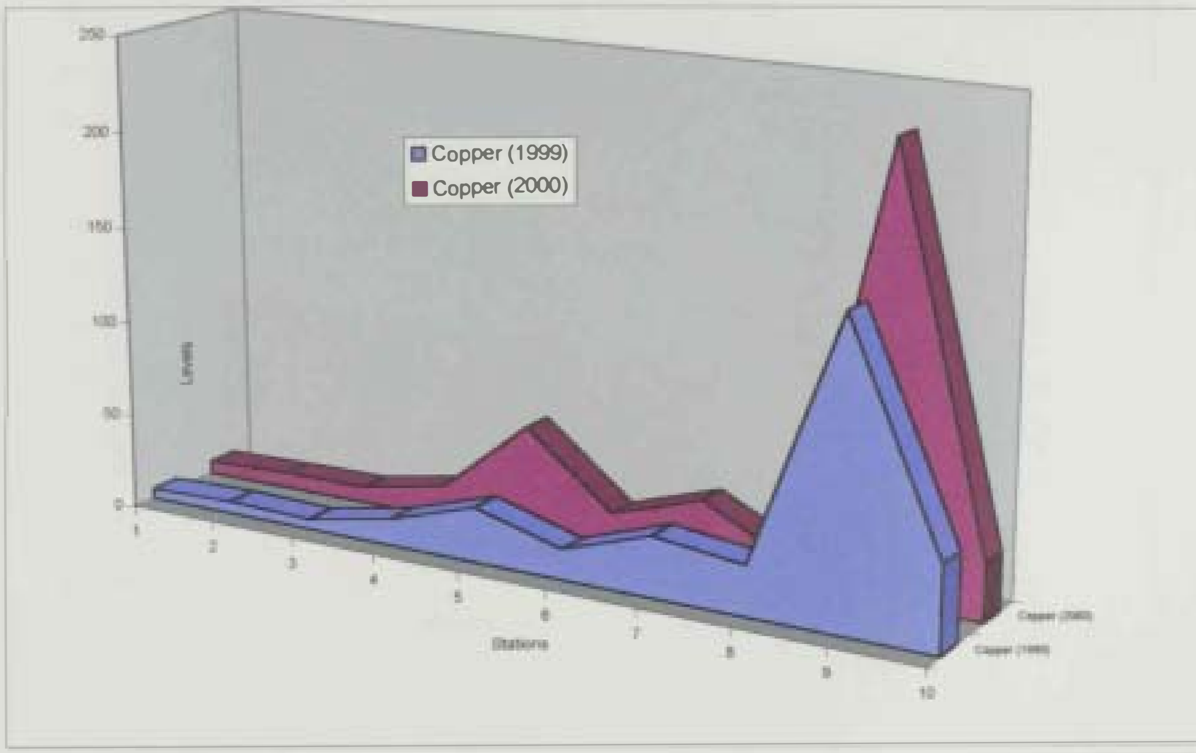


Figure 4.4 *Copper levels (ppm) in the surface sediments along Dubai Creek during 1999-2000*

4.2.5.2 Nickel

Nickel levels show a non-similarity in the range of 20 to 63.5 ppm with a mean value of 29.7 ppm (Figure 4.5). The minimum levels were observed in many stations during 1999, whereas the maximum level was noticed at station 9 during 2000.

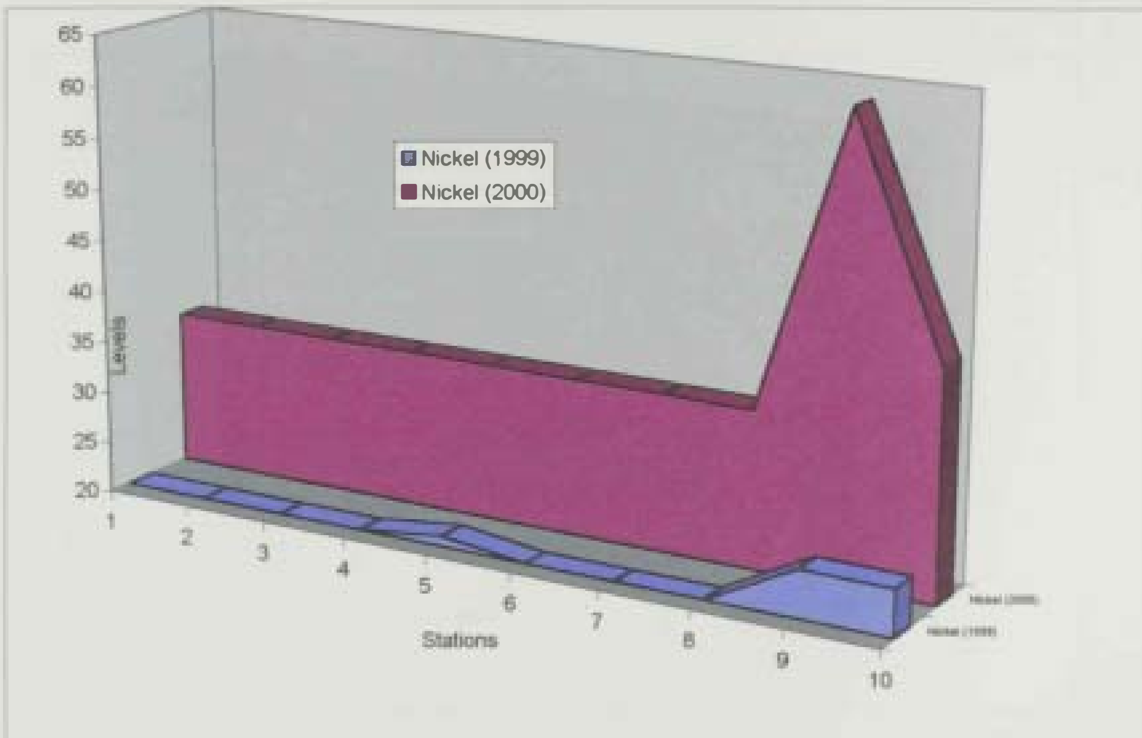


Figure 4.5 *Nickle levels (ppm) in the surface sediments along Dubai Creek during 1999-2000*

4.2.5.3 Lead

Fluctuation in the levels of lead was from 30.1 to 98.2 ppm with a mean value of 55.5 ppm (Figure 4.6). The minimum and maximum levels were observed at stations 2 and 10 respectively during 1999.

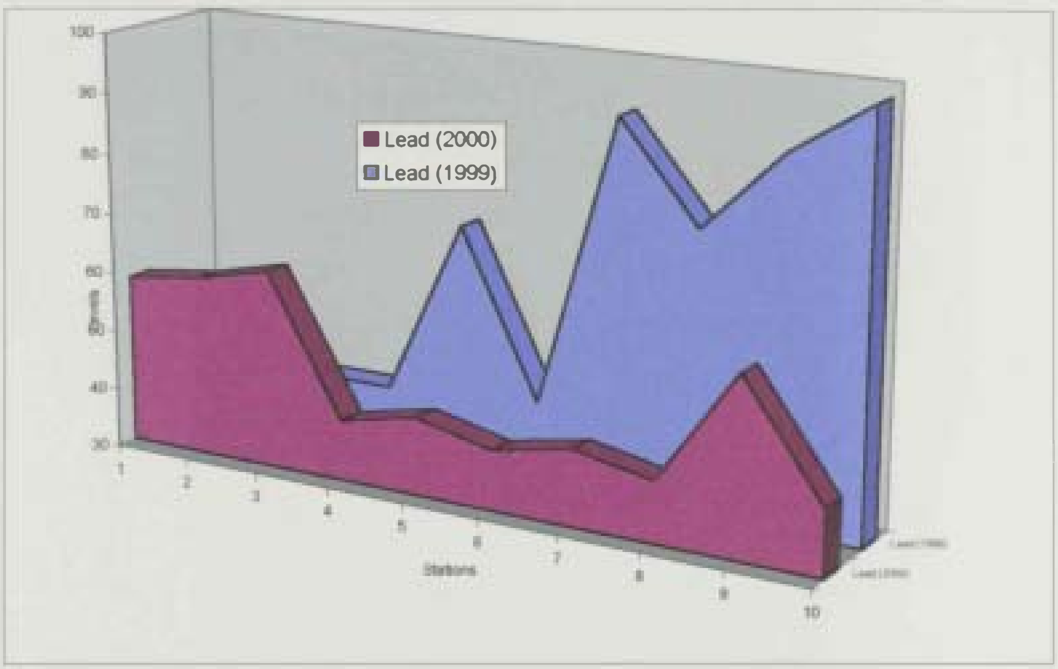


Figure 4.6 *Lead levels (ppm) in the surface sediments along Dubai Creek during 1999-2000*

4.2.5.4 Zinc.

Variation in the levels of zinc was enormous, the observed results show a variation of 7.9 to 776 ppm with a mean value of 131.2 ppm (Figure 4.7). The maximum and minimum levels were observed at stations 1 and 9 respectively during 2000.

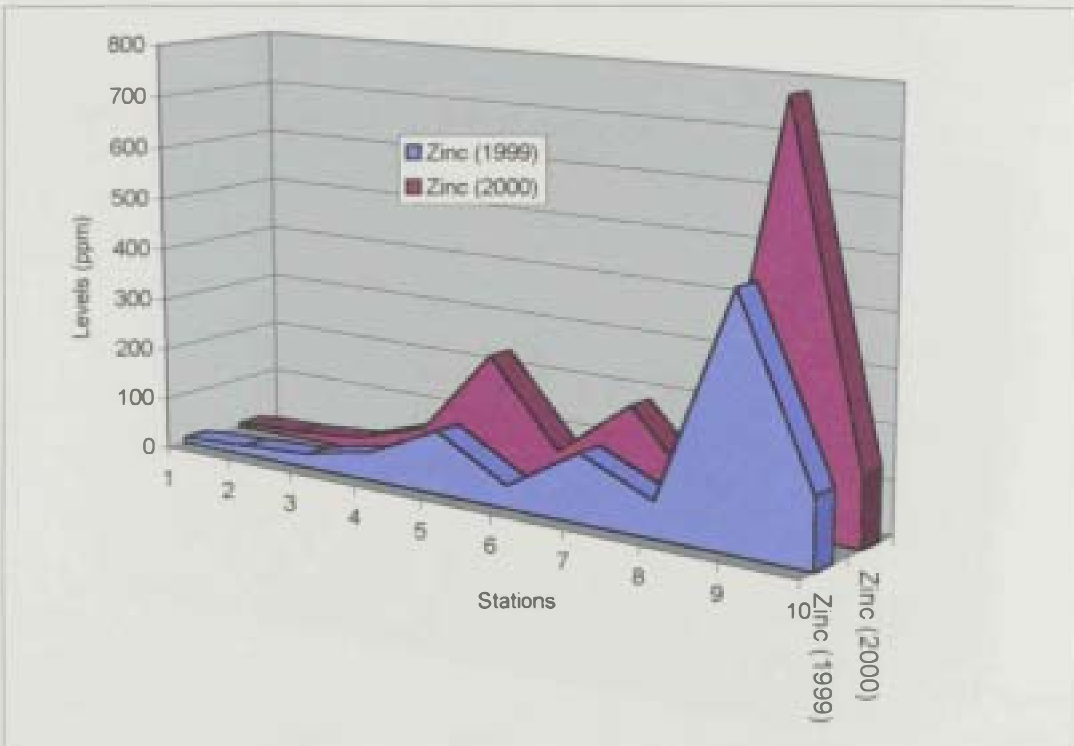


Figure 4.7 *Zinc levels (ppm) in the surface sediments along Dubai Creek during 1999-2000*

4.2.5.5 Chromium

Variation in the level of chromium was in the range of 20 to 82.7 ppm with an average of 43.9 ppm (Figure 4.8). The minimum levels were observed in many stations, while the maximum level was noticed at station 10 during 1999.

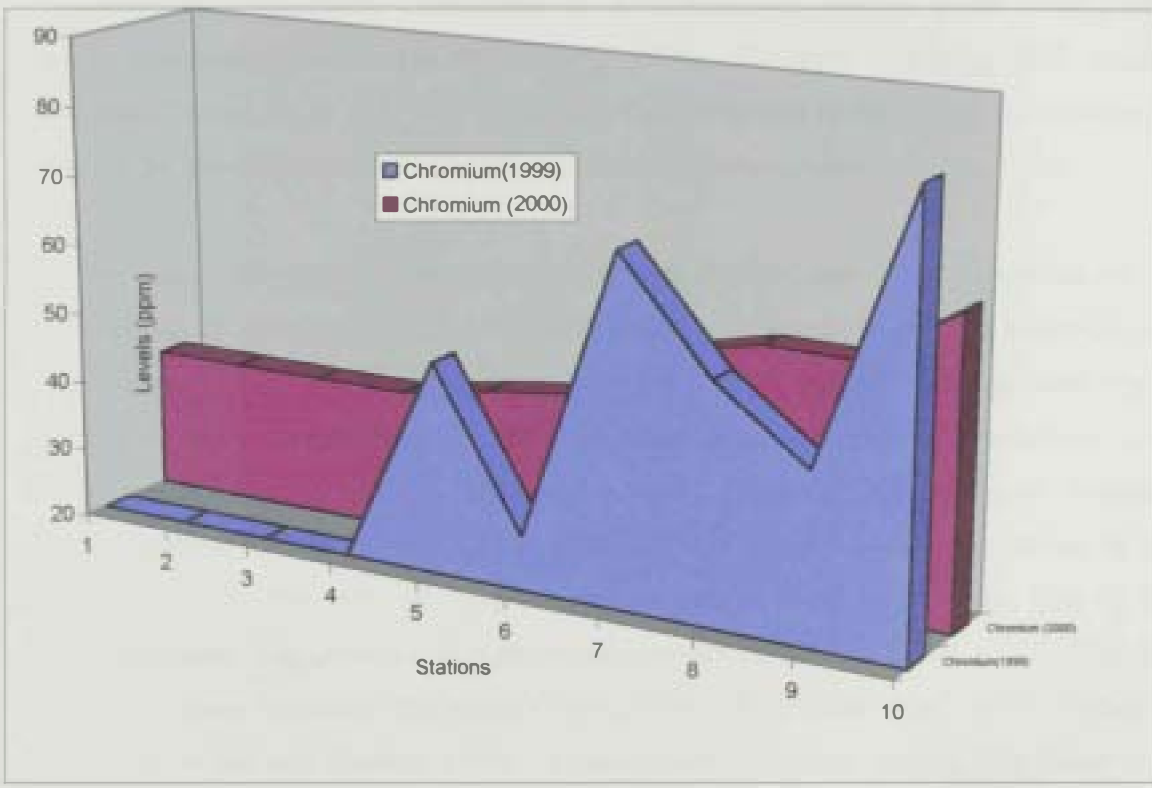


Figure 4.8 *Chromium levels (ppm) in the surface sediments along Dubai Creek during 1999-2000*

4.3 Discussion

Tracing the sources of pollution by the means of water quality gives rise to difficulties, which may usually be ascribed to sampling procedures and the physico-chemical conditions pertaining to the investigated location rather than to the accuracy and precision of the analytical techniques. Furthermore, some trace pollutants get rapidly fixed to the particulate matter and removed from the water column (Förstner and Wittman, 1981). The pollutants absorbed by the particulate matter are ultimately transferred to the bed sediment. The establishments of metal levels therefore play a key role in detecting pollution sources in the marine coastal ecosystem.

Trace metals are natural constituents of all environments and are found in sea water, marine organisms, and sediments (Bryan, 1976). Therefore, knowing their natural background levels, or at least their background concentration in the marine environment is essentail for detecting and assessing the trace metal pollution (Anderlini *et al.*, 1986).

The statistical analysis shows interesting relationship among the concentrations of heavy metals in the stations of Dubai Creek. In overall, data reveal that the concentrations of heavy metals (*Cu, Ni, Pb, Zn and Cr*) in Dubai Creek is higher at the upstream region (stations 4-10) as compared to the downstream region (stations 1-3). The sediments along the upstream region are anoxic, black and odorous, containing high moisture. Sediment texture analysis shows that the Creek is sandy with slighltly high mud content in the upstream region. The level of organic carbon and moisture contents are high in the upstream region. The presence of high organic content on the top layers of sediments are reported in many regions of the world (Young *et al.*, 1973; Eisler *et al.*, 1977; El-Sayed, 1982; Abu-Hilal and Bardan, 1990). Dubai Creek upstream region also shows high levels of organic carbon content comparing to the polluted mangrove area of Khor Abu Dhabi, Khor Umm Al-Quwain, Khor Ras Al-Khaimah and Khor al-Khwair (Shriadah, 1999).

During the present investigation, the levels of copper (5.2-228.6 mean±S.D 37.9±56 ppm); lead (30.1-98.2 mean±S.D 55.5±20.1 ppm); and zinc (7.9-776 mean±S.D

131.2±185.5 ppm) were almost 2 to 5 times higher than the levels of the same metals (copper 3.4-43 mean 15 ppm; lead 2.2-32.8 mean 11 ppm; and zinc 6-142 mean 52.8 ppm) recorded in a previous study conducted at three stations of Dubai Creek by Abu-Hilal and Khordagui (1992). Moreover, the data gathered in 1992 by Abu-Hilal and Khordagui, (*op.cit*) indicated that Dubai Creek and its nearshore sediments have higher range and mean concentration of heavy metals than those of nearby areas of Abu Dhabi, Ajman, and Umm Al-Quwain (Table 4.6). Except for Kuwait (Basaham and Al-Lihaibi, 1993), the present data on Dubai Creek indicate significantly higher averages of heavy metals as compared to regional areas of:- Saudi Arabia (Basaham and Al-Lihaibi, 1993; Fowler *et al.*,1993), Northeast Qatar (Basaham and Al-Lihaibi, 1993), Qatar and Bahrain (Basaham and Al-Lihaibi, 1993) and Bahrain (Basaham and Al-Lihaibi 1993) (Figure 4.9).

Table 4.6 illustrates that during this study, station 9 in Dubai Creek has the highest average concentration of zinc (621.5 ppm); copper (192.8 ppm); lead (74.4 ppm) and nickel (44.1 ppm). Whereas the maximum average level of chromium (73.1 ppm) is recorded at station 10. These results reveal that high concentrations of heavy metals along the upstream region of Dubai Creek is mainly influenced by station 9. At this station, the levels of zinc, copper, lead and chromium are respectively 248, 38, 26 and 2 times higher than the unpolluted surface sediments of the Arabian Gulf (table 4.6). This station is situated close to the Ship Docking Yard (Jaddaf) where ship & traditional wooden dhows repairs and maintenance operations that release anthropogenic pollutants are the major activities. Although, there is a variety of anthropogenic inputs releases from the Ship Yard, the most toxic discharge constituents are heavy metals which rapidly settle into the marine environment. According to Dubai Municipality (2000b), heavy metals in the surface water at station 9 are fluctuating between: 0.9-11 ppb for copper; 0.2-5 ppb for lead; and 0.30-89 ppb for zinc.

It is important to note that mineralogy of the sediment in Dubai Creek has no constrain on the distribution of heavy metals. Mineralogical analysis indicate that sediments from Dubai Creek (upstream region) have almost the same mineralogical composition as the downstream region (Table 4.2).

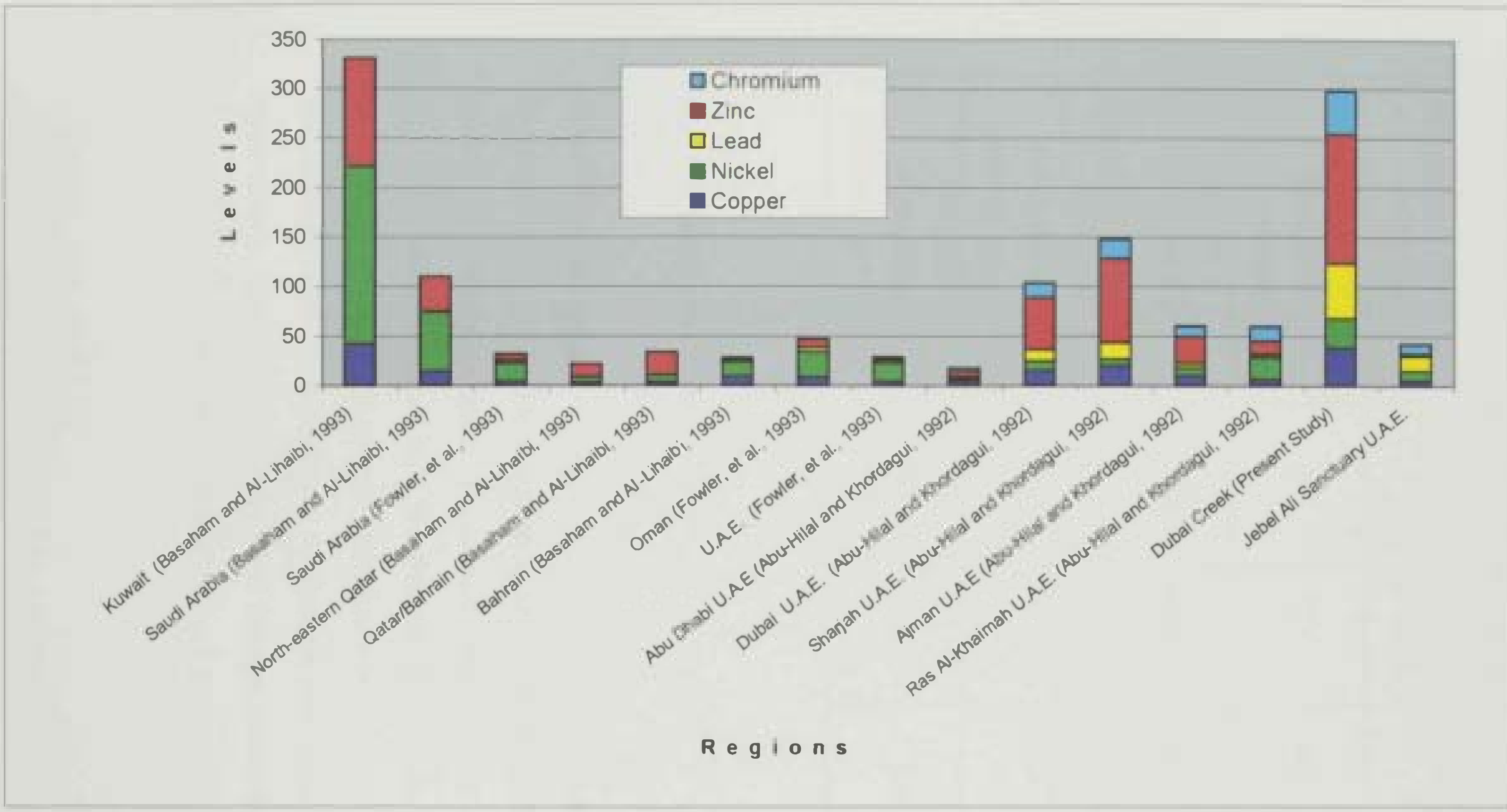


Figure 4.9 *Comparison of heavy metals (ppm) levels in the surface sediments from polluted and unpolluted regions in the Arabian Gulf*

Table 4.6 *Variations in heavy metals levels in the surface sediments along Dubai Creek compared to the Coastal belt and the Arabian Gulf*

Sediments	Cu	Ni	Pb	Zn	Cr
Averages of Dubai Creek (1999-2000)	37.9	29.7	55.5	131.2	43.9
Averages of Upstream (1999-2000)	51.3	30.7	58.4	180.4	49.9
Averages of Downstream (1999-2000)	6.7	27.5	48.7	16.6	30.0
Average of Station 9 (1999-2000)	192.8	44.0	74.3	621.5	49.5
Averages of Reference Station (JabalAli Sanctuary)	5.0	10.0	15.0	2.0	10.0
Averages of Arabian Gulf (Fowler *et al.*,1993)	4.2	18.9	2.9	2.5	-

4.3.1 Cluster Analysis

Cluster analysis separates objects into groups or clusters using measurements on these objects (Davis, 1973). Dendograms is an appealing methods of displaying relationship between multivariate objects. The closest relationship is between nearest objects (Rock, 1988). Linkage refers to how the distance between an object and cluster, or between two clusters (as opposed to two individual objects) is measured. Single linkage reflects the similarities of the two closest or furthest individuals (Rock, 1988). Moreover, the input matrix, similarities measure, and linkage methods affect the appearance of the resulting dendograms. The most-widely used parameters for measuring distance are the correlation coefficient and Euclidean distance (equals the sum of square of differences of N variables values between the points).

To study the similarities between stations, multivariate statistical analysis in the form of cluster analysis had been used. According to Al-Qubaisi (2001), classification is placing of variables into more or less homogenous groups, in a manner so that the relationship between groups is revealed. The simplest form of meaningfully grouping of measured variables is the tree diagrams. The constructed tree diagram (Figures 4.9 and 4.10) during present study indicate similarities between the downstream and stations of Dubai Creek, most of the samples from the upstream stations cluster in high metals contents. However, the tree diagram for station 9 alone indicates very high clusters of the metals contents. Based on the levels (Averages±S.D) of all the heavy metals, the concentration of station 9 is almost six times higher than the average concentration of heavy metals from the downstream region.

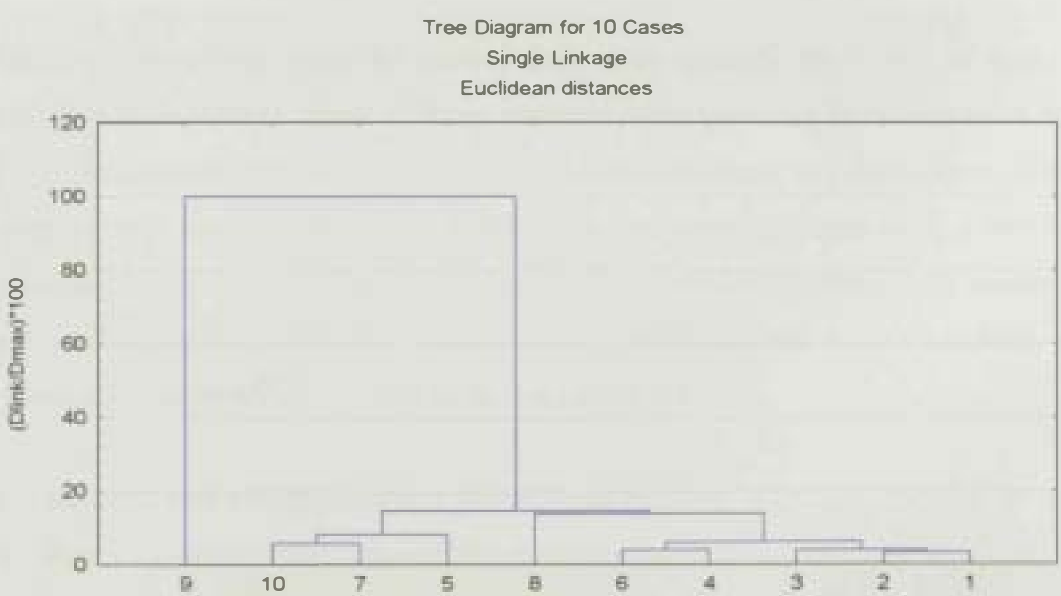


Figure 4.10 *Cluster analysis for heavy metals (Cu, Ni, Pb, Zn, Cr)in the surface sediments along Dubai Creek during 1999*

correlation coefficient and Euclidean distance (equals the sum of square of differences of N variables values between the points).

To study the similarities between stations, multivariate statistical analysis in the form of cluster analysis had been used. According to Al-Qubaisi (2001), classification is placing of variables into more or less homogenous groups, in a manner so that the relationship between groups is revealed. The simplest form of meaningfully grouping of measured variables is the tree diagrams. The constructed tree diagram (Figures 4.9 and 4.10) during present study indicate similarities between the downstream and stations of Dubai Creek, most of the samples from the upstream stations cluster in high metals contents. However, the tree diagram for station 9 alone indicates very high clusters of the metals contents. Based on the levels (Averages±S.D) of all the heavy metals, the concentration of station 9 is almost six times higher than the average concentration of heavy metals from the downstream region.

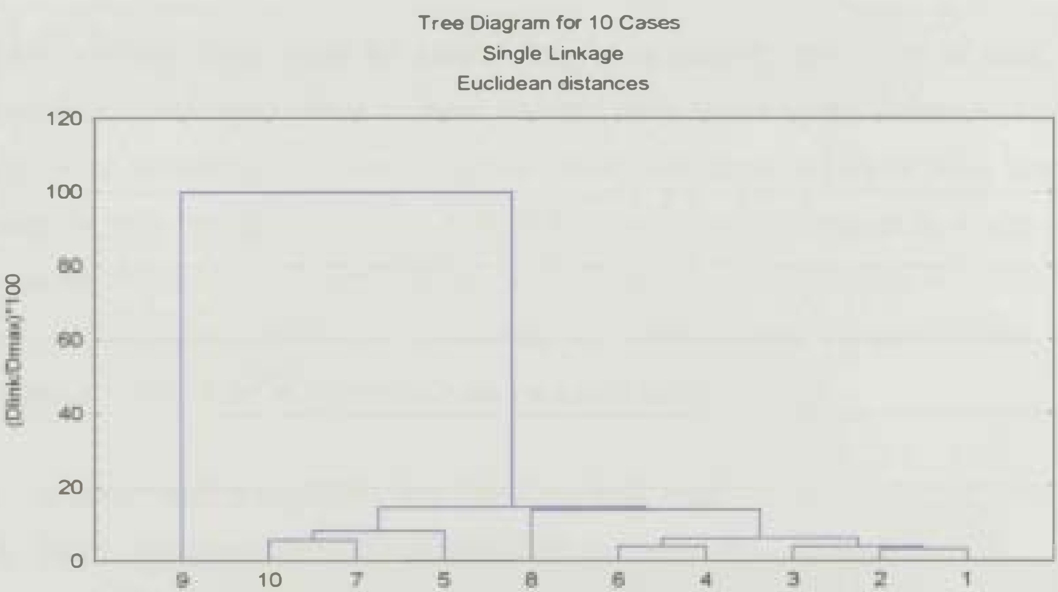


Figure 4.10 *Cluster analysis for heavy metals (Cu, Ni, Pb, Zn, Cr)in the surface sediments along Dubai Creek during 1999*

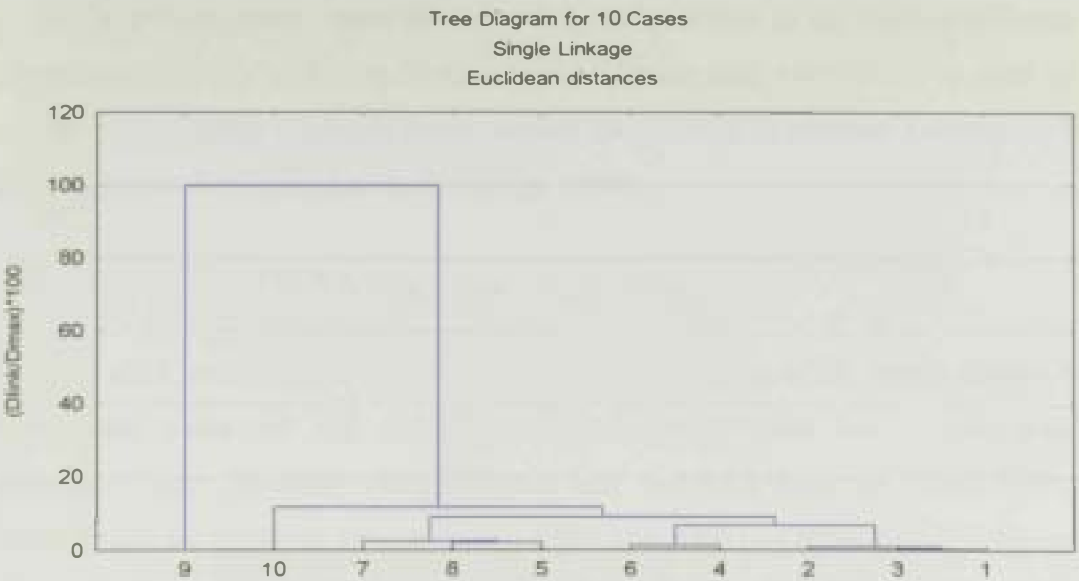


Figure 4.11 *Cluster analysis for heavy metals (Cu, Ni, Pb, Zn, Cr) in the surface sediments along Dubai Creek during 2000*

4.3.2 Quantification of Metal Pollution

Many attempts were made by several authors to quantify the extent of heavy metal pollution in sediments. Most of these attempts were based on the comparison between the metal concentrations recorded in the studied sediments and those in an unpolluted areas or with background values. The background concentrations or in a very specific term the "natural level" (Precivilization level), are the concentration of metals before any anthropogenic influences. According to Salomons and Förstner (1984), several means are used in order to establish the background level:

1. Average shell composition as a global standard level.
2. Fossil aquatic sediments from defined environments as a standard.
3. Recent deposits in relatively unpolluted areas.
4. Short-dated sedimentary core, which provides a historical record of the events occurring in the watershed.

In the present study, quantification of metal pollution in the studied sediment was attempted using the "Pollution Load Index". Pollution load index (PLI) is used to find out the mutual effect of the different studied metals. PLI is calculated according to the following equation (Salomons and Förstner 1984).

$$PLI = \sqrt[5]{CF_{Ni} \times CF_{Cu} \times CF_{Cr} \times CF_{Pb} \times CF_{Zn}}$$

CF is the Contamination Factor. CF is the concentration of the metals divided by the background value for this metal. Background value used here is the limestone (Salomons and Förstner, 1984). Figures 4.11 and 4.12 show the values of PLI in Dubai Creek for different stations during 1999 and 2000 respectively, while Figure 4.13 shows the distribution of PLI along Dubai Creek. Despite low PLI values as compared to other areas (Tomlinson *et al.*, 1980; El-Sammak, 1995), It is obvious that the upstream region of the Creek exhibits higher values as compared to the downstream.

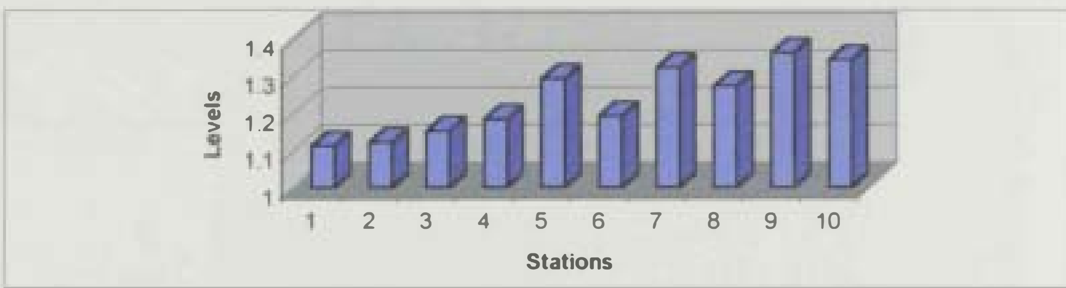


Figure 4.12 *Pollution Load Index along various stations in Dubai Creek during 1999*

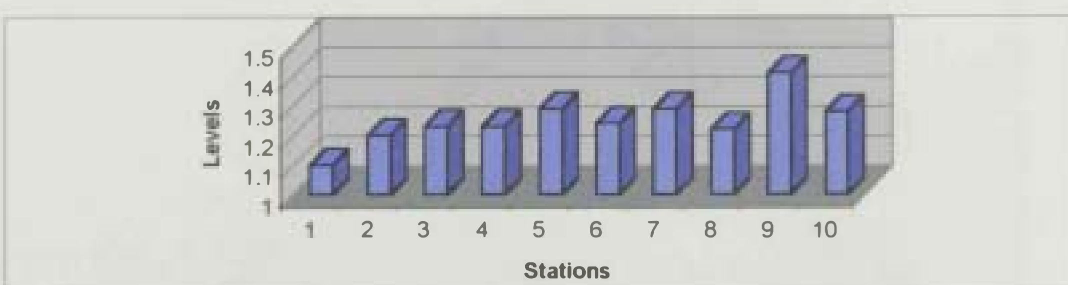


Figure 4.13 *Pollution Load Index along various stations in Dubai Creek during 2000*

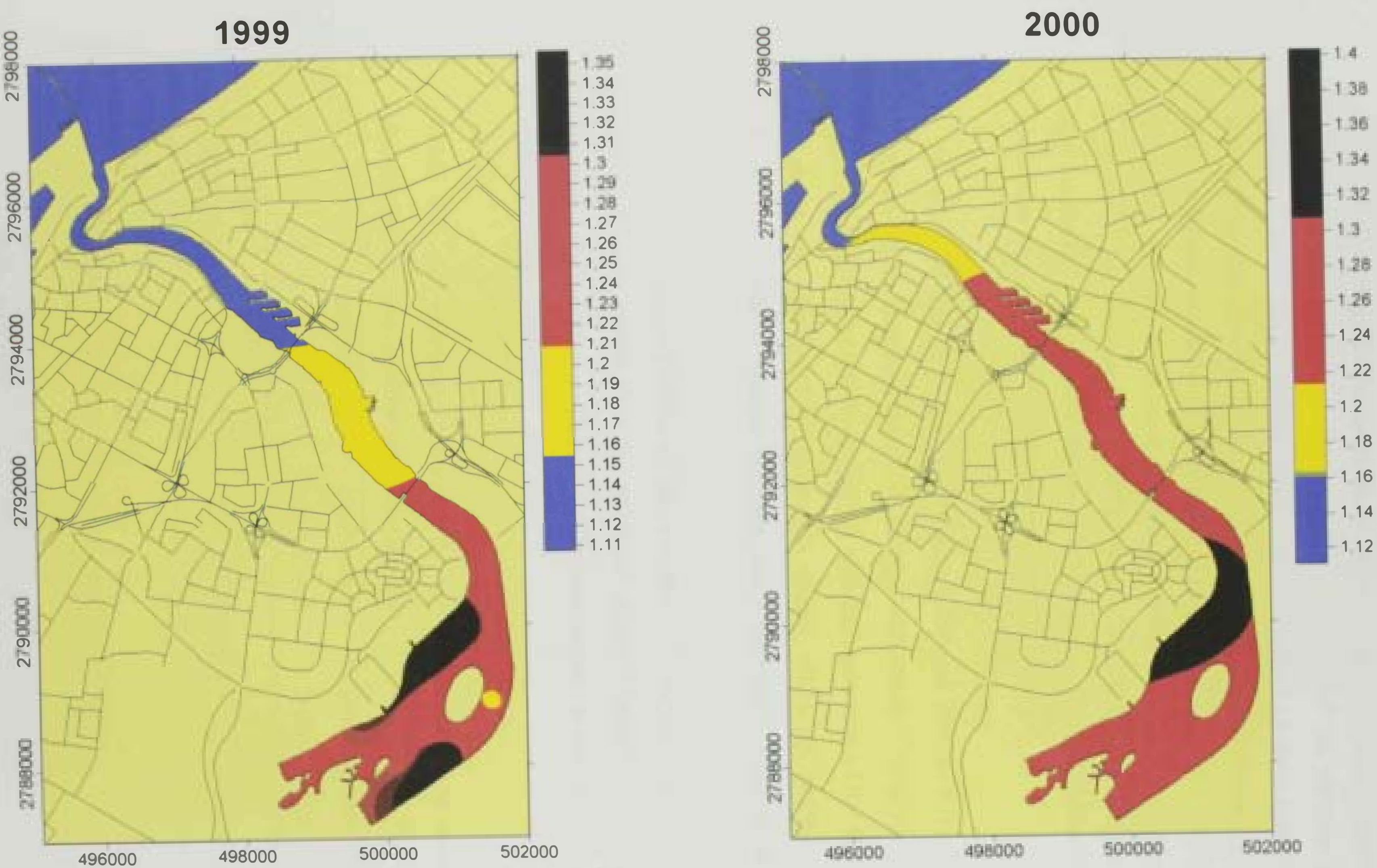


Figure 4.14 *Pollution load index (PLI) along Dubai Creek during 1999-2000*

Typical characteristics of sediments along upstream stations are the presence of high concentration of heavy metals at the top layer. The concentration of copper and zinc are 6 to 10 times respectively higher at the top layer (0-4 cm)as compared to the bottom layer (12-16 cm) of bed sediments in the upstream of Dubai Creek (Dubai Municipality, 1997b). This feature of sediments was reported earlier in the 1-2 cm of the top layer from the upstream stations of Dubai Creek in 1992, where the levels were 2-18 times higher than of the bulk sample (Abu-Hilal and Khordagui, 1992). El-Sammak (2001) indicated the same results for the Dubai sediments, where the upper layers were almost enriched with heavy metals as compared to the layers below. These results are also consistent with many previous reports from many regions of the world (Young *et al.*, 1973; Eisler *et al.*, 1977). The presence of such distinctly high concentration of metals at the top layer of recently deposited surface sediments is usually common in the areas receiving anthropogenic inputs.

The levels of chromium were high during 1999 and 2000 at station 10. However, the upstream region in general is highly polluted with metals. The probable reason for these high concentrations could be associated with the movement of the metal towards station 10 along with the plume of particulate matter, which got settled, instead of getting flushed out, this is because the area has a very poor flushing capacity (Halcrows, 1992).

Based on the comparison of the average PLI, station 9 contains 23 times higher levels of heavy metals than the reference station (Table 4.7). The downstream, and upstream regions also contain 3 to 9 times higher levels of heavy metals than the reference station.

Table 4.7 *Comparisons between PLI for heavy metals at station 9 and upstream, downstream regions, and the reference station*

	Station 9	**Upstream Dubai Creek**	**Downstream Dubai Creek**	**Reference Station**
Averages	165	63	23	7
Ratio	23	9	3	1

The negative correlation of heavy metals concentrations with salinity during 1999 and 2000 indicates that heavy metal pollution in Dubai Creek is associated with anthropogenic freshwater inputs (Table 4.8).

Table 4.8 *Correlation matrix for salinity vs. heavy metals along the surface sediments of Dubai Creek during 1999-2000*

	Cu	Ni	Pb	Zn	Cr	Salinity
Cu	0.0	-	-	-	-	-0.75
Ni	-	0.0	-	-	-	-0.75
Pb	-	-	0.0	-	-	-0.73
Zn	-	-	-	0.0	-	-0.77
Cr	-	-	-	-	0.0	-0.72
Salinity	-0.75	-0.75	-0.73	-0.77	-0.72	0.0

The sediments in Dubai Creek are rapidly receiving the heavy metals in the upstream region particularly at station 9 from anthropogenic sources. The present levels of heavy metals in the sediments demonstrate that copper, lead, and zinc from Dubai Creek are 9, 19 and 52 times respectively higher than the levels reported from the unpolluted marine sediments of the U.A.E. (Fowler *et al.*, 1993).

The present assessment indicates that station 9 is identified as the most polluted site along Dubai Creek. This is because the heavy metal contents have been increased by : 309 ppm for zinc, 71.6 ppm for copper, 39.5 ppm for nickel, and 10.8 ppm for chromium within one year (1999-2000). This assessment calculated that the daily accumulation rate of 0.85 ppm for zinc, 0.20 ppm for copper, 0.10 ppm for nickel, and 0.03 ppm for chromium (Table 4.9) .

Table 4.9 *Levels of heavy metals (ppm) at station 9 during 1999 and 2000*

Levels	Zinc	Copper	Nickel	Chromium	Lead
1999	467	157	24.6	44.1	89.5
2000	776	228.6	63.5	54.9	59.2
Difference 1999-2000	309	71.6	39.5	10.8	-30.3
Daily accumulation	0.85	0.20	0.10	0.03	Nil

In overall, the following conclusions can be drawn from this study:-

1. Zn, and Pb levels in the surface sediments are 35 times higher than those found in the U.A.E. unpolluted marine sediments as reported in 1993.

2. The existing levels of heavy metals in Dubai Creek are 2-5 times higher than the earlier records of 1992.

3. Compared to the reference station of Jabal Ali, the levels of heavy metals are 8 times higher in the upstream region, and 23 times higher at station 9.

4. The levels of Zn, Cu, Pb and Cr are respectively 248, 38, 26 and 2 times higher than the unpolluted surface sediments of the Arabian Gulf as reported in 1993.

5. The major source of anthropogenic contaminants in the upstream region is Outfall No. 24.

6. The most contaminated site of the Creek is station 9 and its environs, where the daily accumulation rates of zinc, copper, nickel and chromium in the sediments are 0.85, 0.20, 0.10 and 0.03 ppm respectively.

CHAPTER V

GENERAL DISCUSSION

General Discussion

5.1 Introduction

With the growth of technology and industry and efforts of removing man-made pollutants from the natural environment, the coastal waters had been transformed into sewage depots where the natural biologic balance is severely upset and in some cases totally disrupted.

Two groups of substances in particular have a lasting effect on the natural balance in aquatic systems: a) nutrients, which promote unrestricted biological growth and in turn, oxygen depletion, and; b) Sparingly degradable synthetic chemicals and other waste substances which often constitute multiple adverse effects on the aquatic ecosystem (Förstner and Wittman, 1981).

It is estimated that industrial and domestic wastewater introduces upto a million different pollutants into natural waters. These include substances that are not considered dangerous, although many of them add a disagreeable odour or taste to the water, and others significantly upset the ecosystem without being directly harmful to humans. Other groups do, however, have direct and indirect influences on the human organism and can cause serious damage (Förstner and Wittman, 1981).

Trace metals are among the second group which cause direct influences on the human organism. Trace metals are of note in two respects: firstly, they are not usually eliminated from the aquatic ecosystems by natural processes, in contrast to most organic pollutants; and secondly, most metal pollutants are enriched in mineral and organic substances. Toxic metals tend to accumulate in bottom sediments from which they may be released by various processes of remobilization, and -in changing form -can move up the biologic chain, thereby reaching human beings where they produce chronic and acute ailments (Förstner, and Wittman, *op. cit*).

Environmental models may be divided into three groups: first, there are descriptive models involving sentences, diagrams or maps; second, there are empirical models involving the collection and plotting of data; and third, there are theoretical models involving the formal statement of processes which link prameters of interest (Hardisty *et al.*, 1993).

IMO/ FAO/ UNESCO/ WMO/ WHO/ IAEA/ UN/ UNEP studies (GESAMP, 1991) have expressed the need for advice on the art of modeling in coastal environments, in relation to understanding the transport, dispersion and fate of contaminants disposed of in the coastal marine environment.

Modeling for marine pollution studies is very important because all biological, chemical, geological, and physico-chemical processes can affect the transport, dispersion, and the fate of marine contaminants.

Informations on modeling from Dubai Creek is very limited. Few studies on numerical modeling have been carried out during the improvement of Dubai Creek project (Halcrows, 1992). However, these models are two dimensional and restricted mainly to the current patterns, and flushing within the Creek. Most of the available information on modeling has been taken from the references on sediment transport reports and studies on coastal modeling (GESAMP, 1991, Reynold, 1993).

In this investigation the procedures by which this assessment is conducted is based on a comprehensive scientific data of Dubai Creek that might impose on that environment and human.

5.2 Distribution of Different Parameters

5.2.1 Water Quality

5.2.1.1 Temperature

The distribution pattern of the water column averages of temperature in the Creek does not show much variation, the annual variation were very limited during 1999 and 2000 (Figure 5.1).

5.2.1.2 Salinity

Salinity along the Creek shows a slightly distinct pattern of distribution. The water column average shows the influx of freshwater into the upstream region of Dubai Creek. Figure 5.2 clearly demonstrates the influx of freshwater during 1999 and 2000.

5.2.1.3 pH

The patterns of pH distribution indicate the alkaline state throught out Dubai Creek (Figure 5.3). It also indicates that upsream region is more alkaline than the downstream region during 2000.

5.2.1.4 Dissolved Oxygen (DO)

DO shows high average levels in the Creek (Figure 5.4). High levels are demonstrated in the upstream region particularly beyond the Island in the lagoon of Dubai Creek .

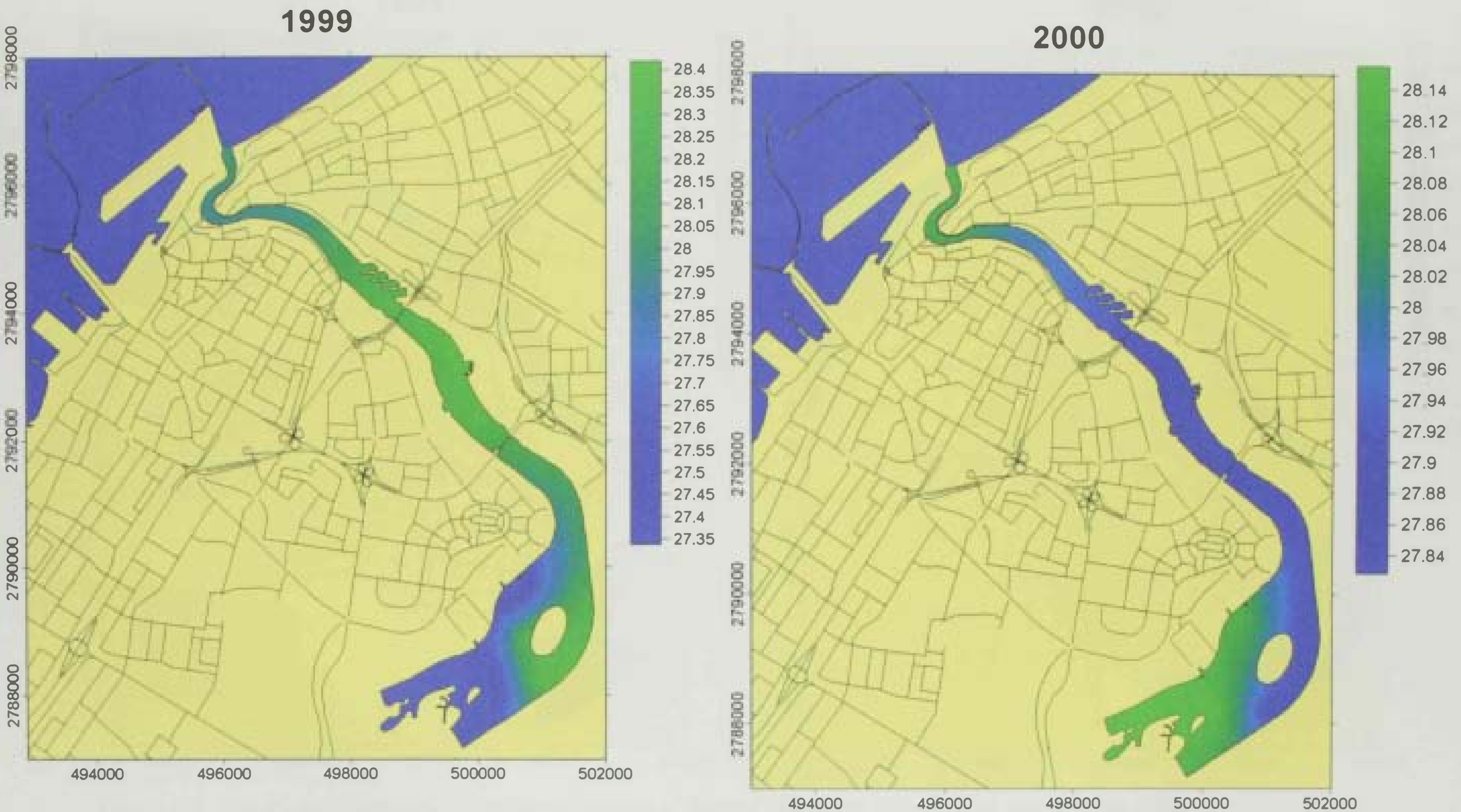


Figure 5.1 *Model showing annual distribution pattern of Water temperature (°C) along Dubai Creek during 1999-2000*

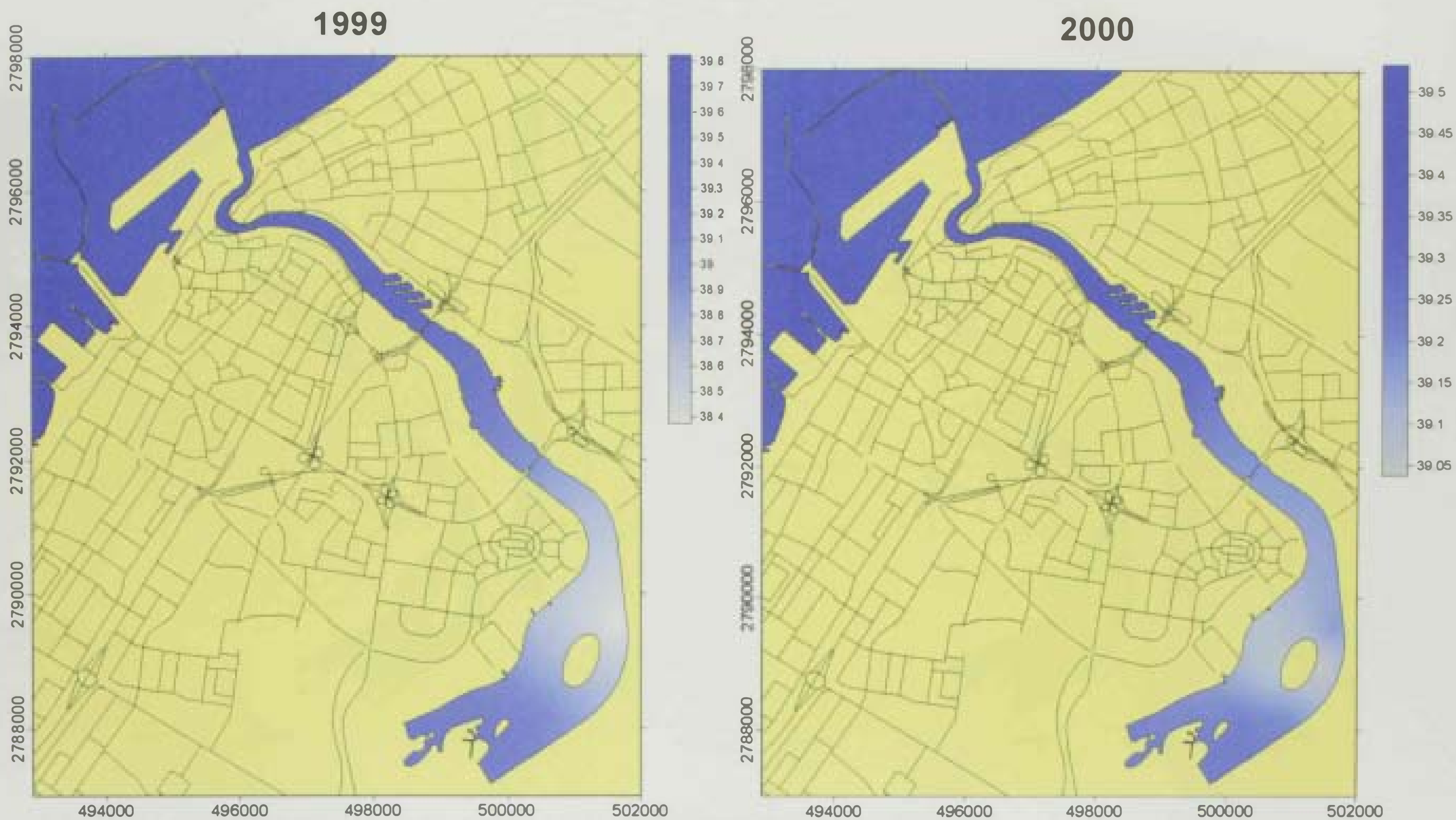


Figure 5.2 *Model showing annual distribution pattern of Salinity (‰) along Dubai Creek during 1999-2000*

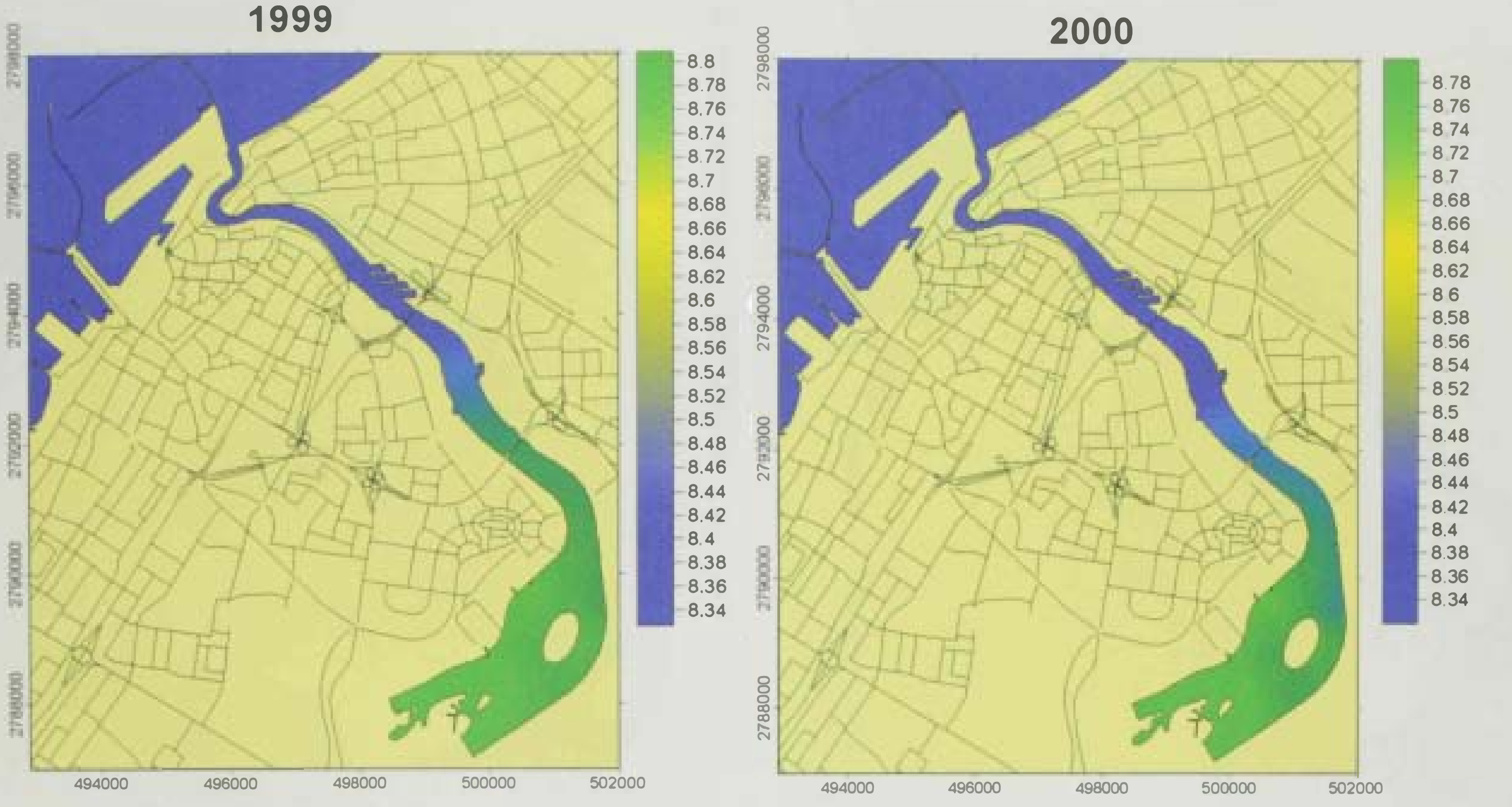


Figure 5.3 *Model showing annual distribution pattern of pH along Dubai Creek during 1999-2000*

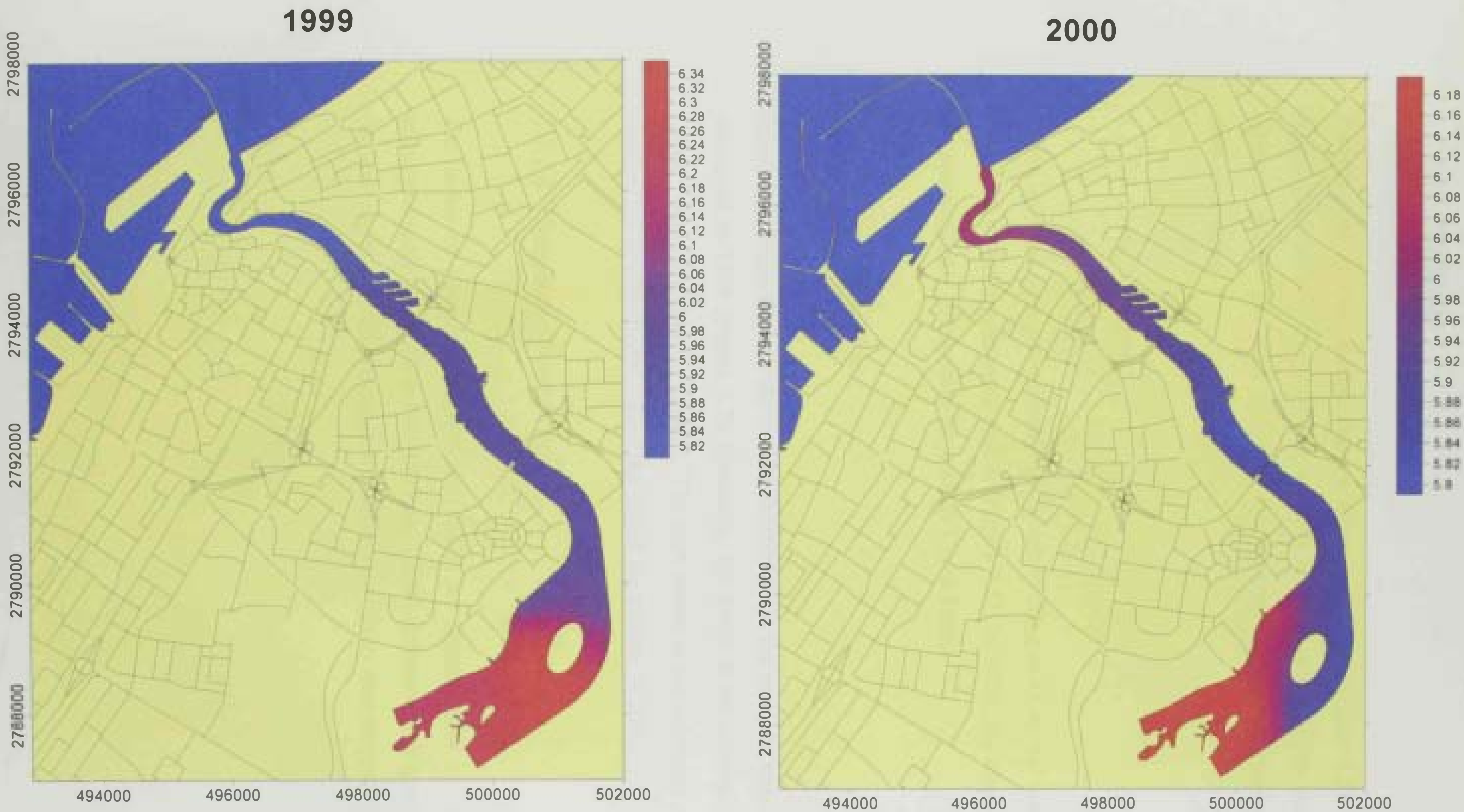


Figure 5.4 *Model showing annual distribution pattern of Dissolved Oxygen (DO) mg/l along Dubai Creek during 1999 and 2000*

5.2.1.5 *Turbidity*

Turbidity shows two distinct regions along the Creek (Figure 5.5). The downstream region (stations 1-3) shows lower turbidity levels as compared to the upstream region (stations 4-10). The high levels in the upstrem region are attributed to the high planktonic algae.

5.2.1.6 *Total Nitrogen*

Levels of total nitrogen reflects high levels (>50μg-at/ℓ) in the upstream region as compared to the downstream region (Figure 5.6). In 2000, the levels covered most of the upstream part particularly beyond the Creek Island.

5.2.1.7 *Nitrate-nitrogen*

Levels of nitrate-nitrogen show wide fluctuation in the upsteam region during 2000 as comapred to 1999 (Figure 5.7). Generally, the levels in the downstream section of the Creek were less than 30 μg-at/ℓ. The high levels in the upstream region, particulary towards the southern-west side of the Island are evident in 2000.

5.2.1.8 *Phosphate-phosphorus*

The levels of phosphate-phosphorus make a demarcations of high levels in the vicinity of station 4 and 9 during 1999 and 2000 respectively (Figure 5.8). In general, the levels of phosphate-phosphorus in 2000 were lower than those of 1999.

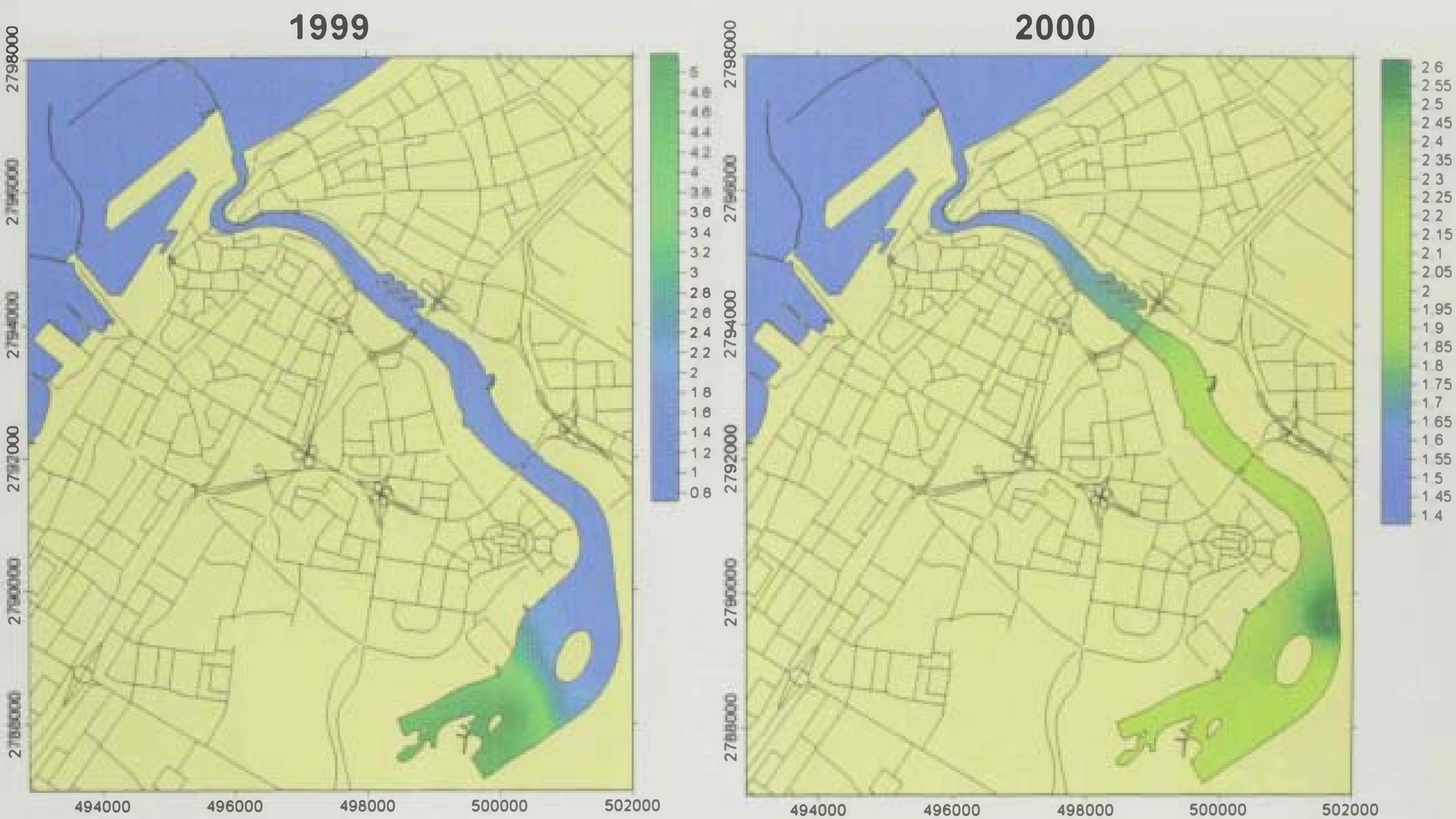


Figure 5.5 *Model showing annual distribution pattern of Turbidity (NTU) along Dubai Creek during 1999-2000*

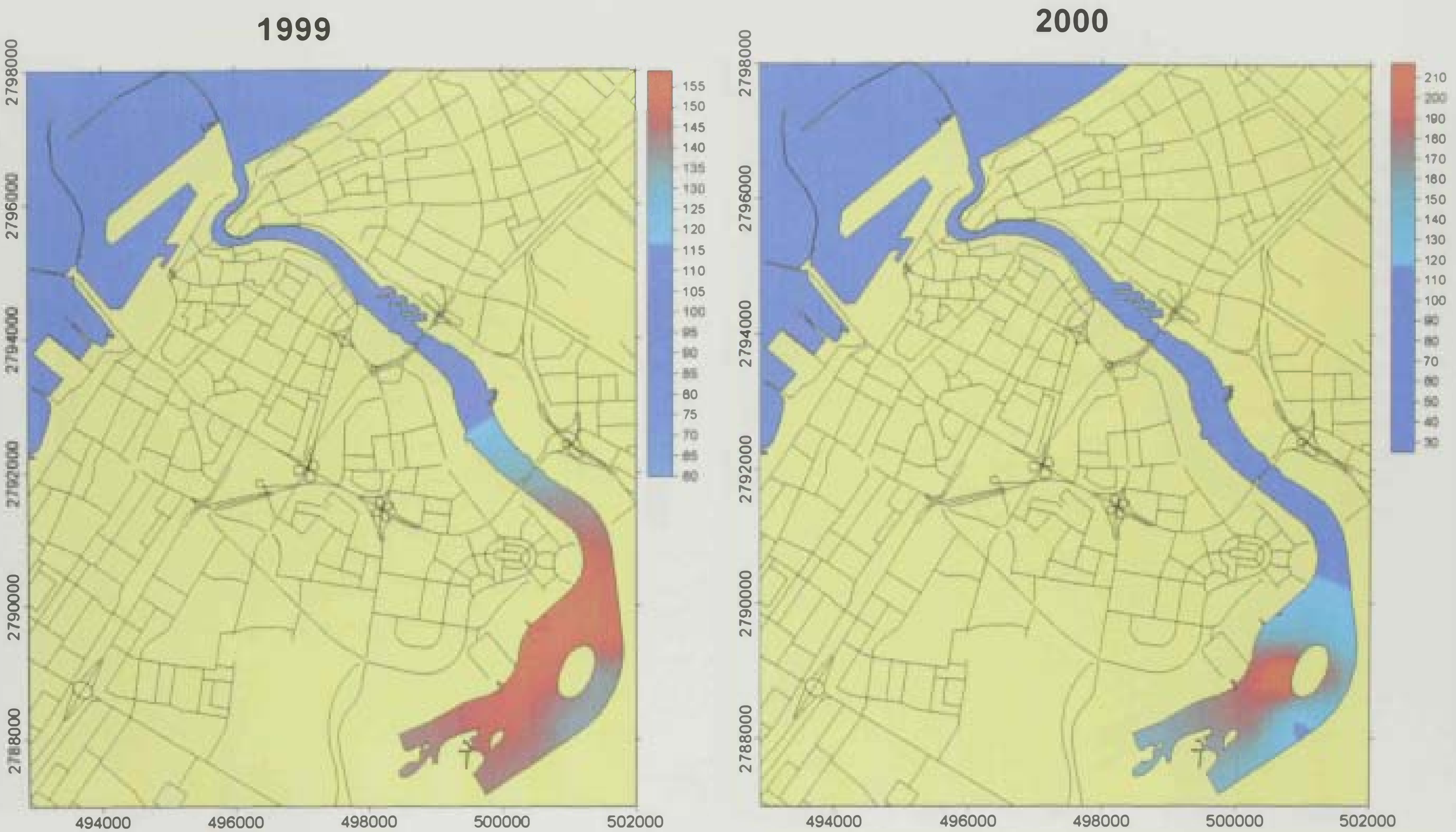


Figure 5.6 *Model showing annual distribution pattern of Total Nitrogen (µg-at/l) along Dubai Creek during 1999-2000*

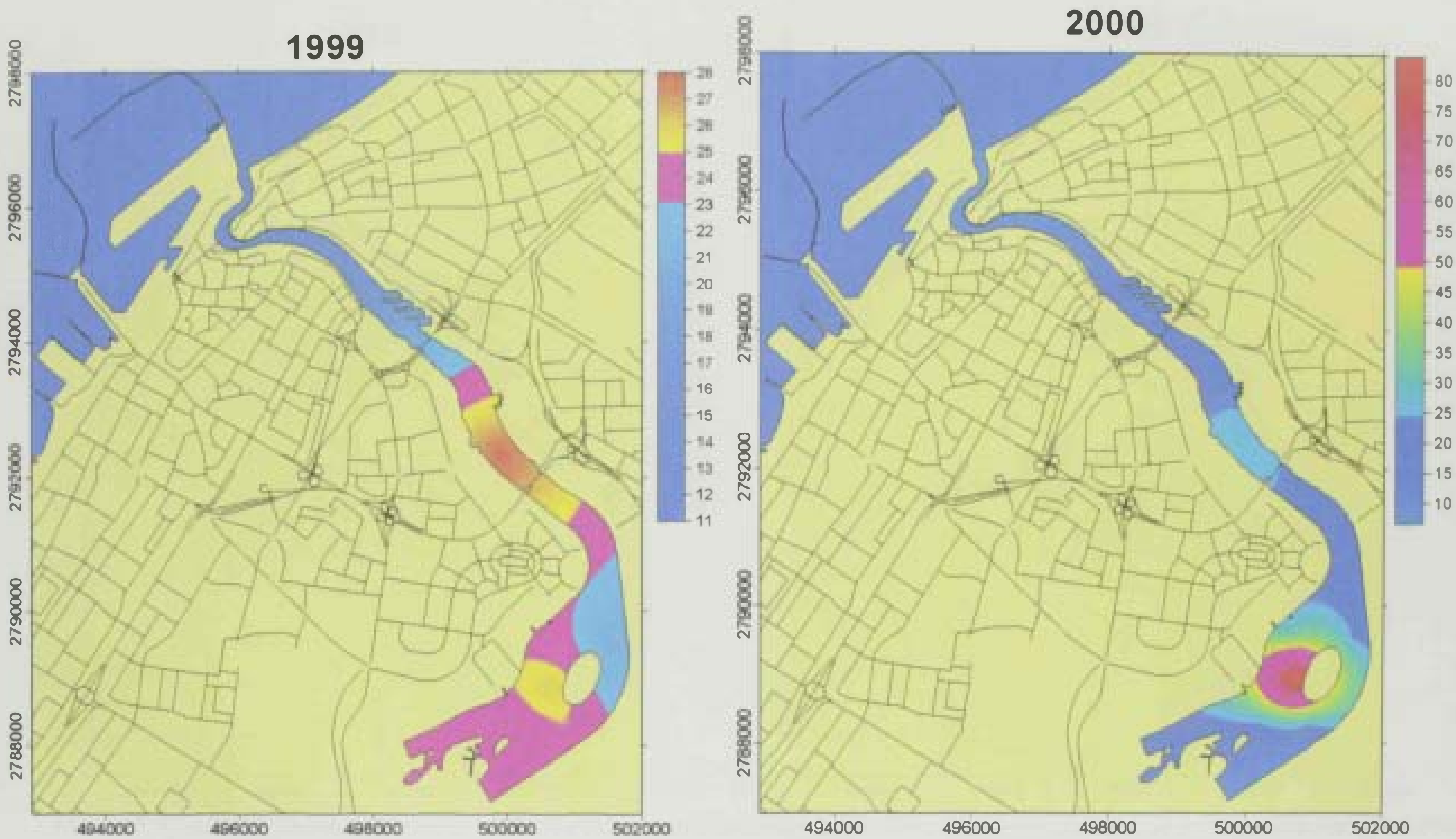


Figure 5.7 *Model showing annual distribution pattern of Nitrate-nitrogen (µg-at l) along Dubai Creek during 1999-2000*

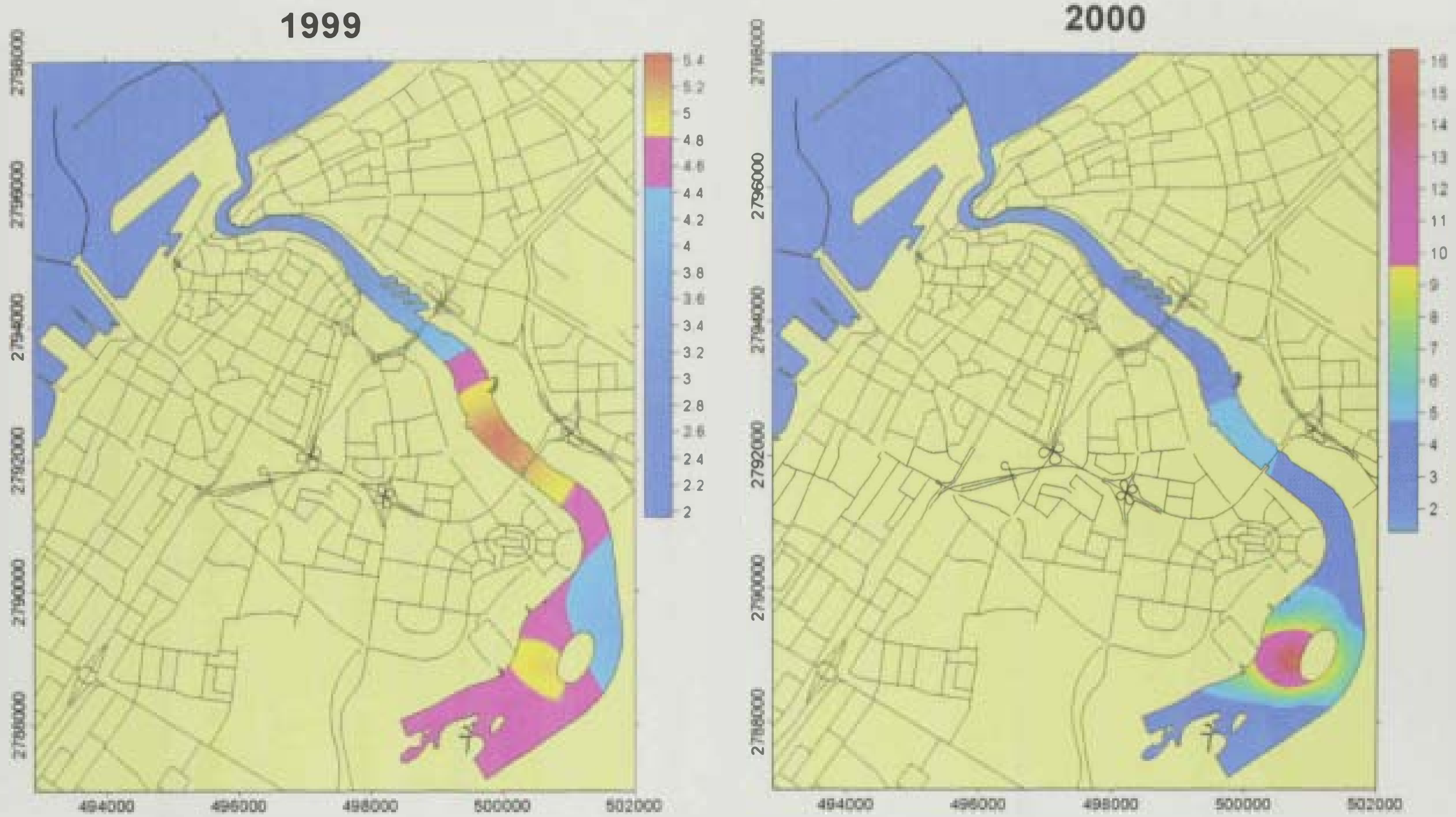


Figure 5.8 *Model showing annual distribution pattern of Phosphate-phosphorus (µg-at/l) along Dubai Creek during 1999-2000*

5.2.2 Sediment Quality

5.2.2.1 Moisture Content

Sediments show a high moisture contents in the Creek particularly along the upstream region of the Creek (Figure 5.9).

5.2.2.2 Organic Carbon

The levels of organic carbon show high contents towards northeast area of Dubai Creek upstream region (Figure 5.9).

5.2.2.3 Texture Analysis (Mud and Sand)

The Creek shows high content of mud in the upstream region (Figure 5.10). In the downstream region upto station 4, the Creek contain more than 98 percent of the sand (Figure 5.10). Sand shows just the reverse trend of mud along Dubai Creek

5.2.2.4 Heavy metals (Cu, Ni, Pb, Zn and Cr)

Copper shows a clear plume of high sediment concentration that starts from station 9 through station 5 during 1999 and 2000 (Figure 5.11). It is evident from the results that the plume along stations 5 and 8 is insignificant, and the levels are more or less similar to the downstream region.

Nickel shows similar trend to the plume of copper in the surface sediments (Figure 5.12). However, the plume starts from station 9 and covers south-west periphery region of the upstream area during 1999 and 2000.

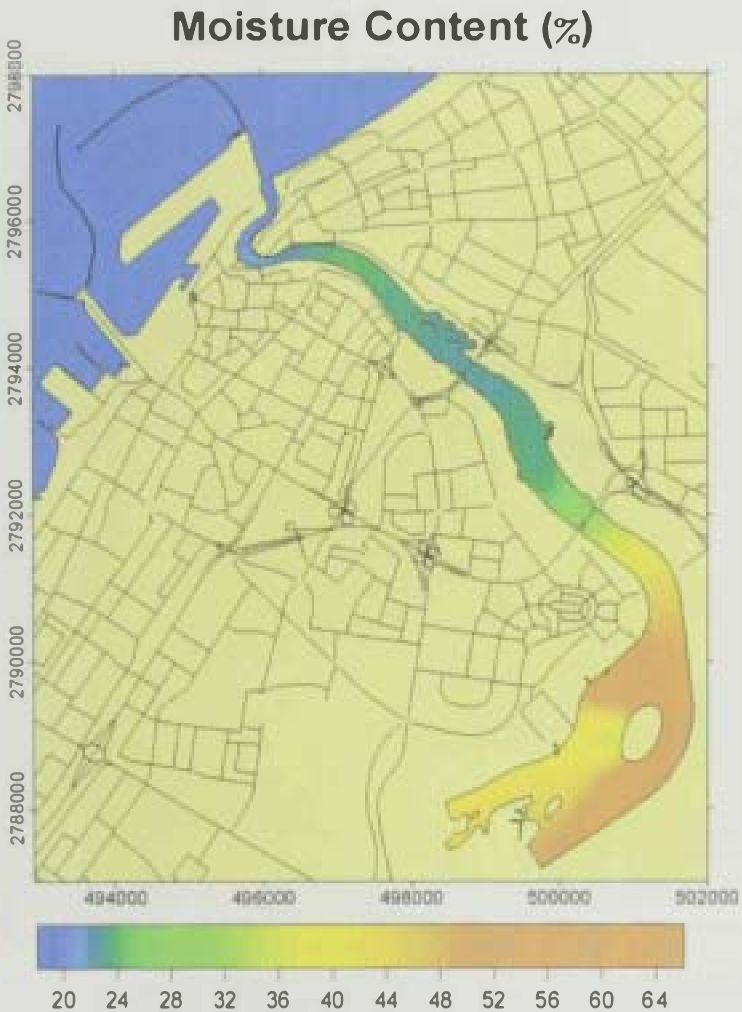


Figure 5.9 *Models showing annual distribution pattern of Moisture Content (%) and Organic Carbon (%) in the surface sediments along Dubai Creek during 2000*

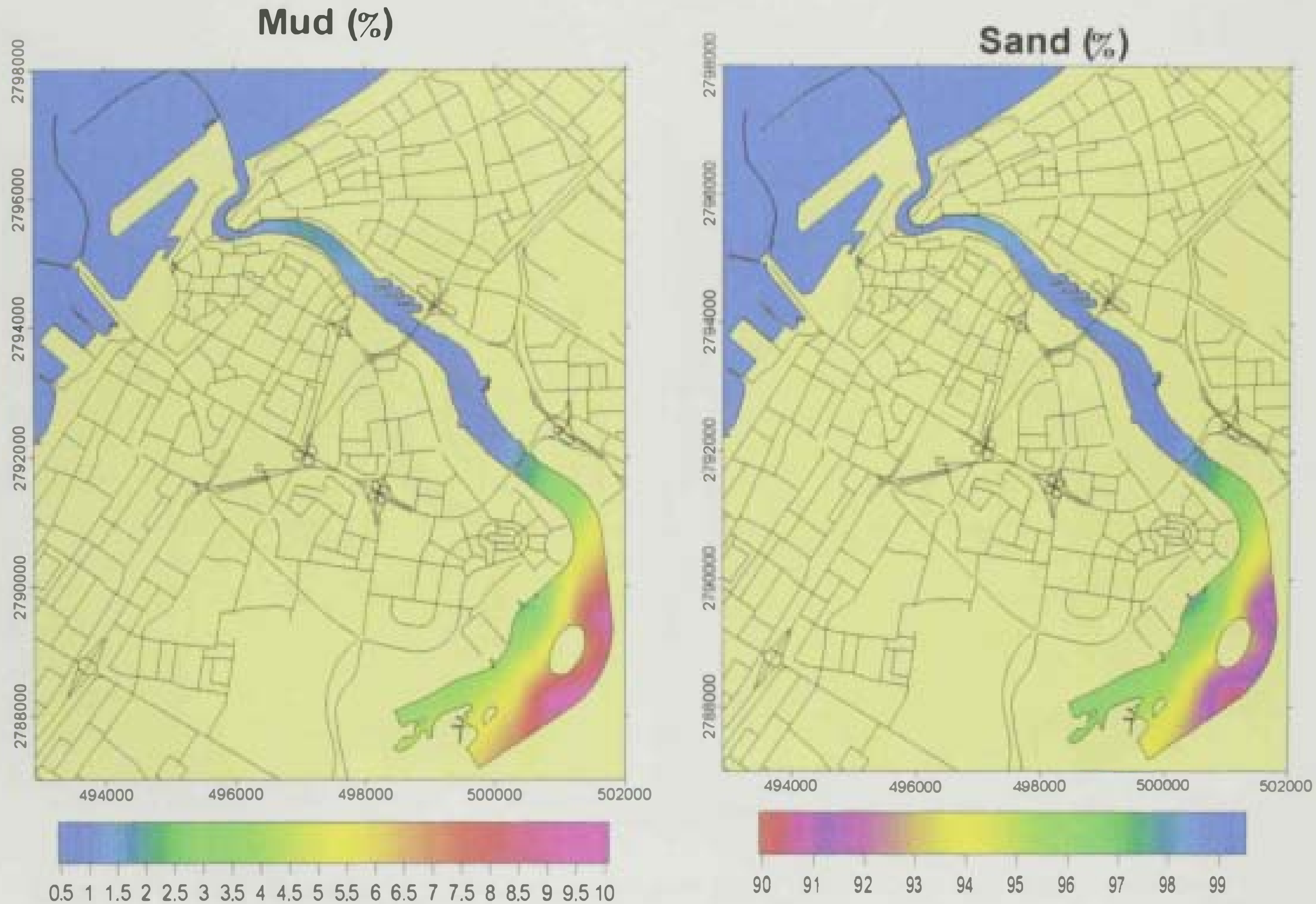


Figure 5.10 *Models showing annual distribution pattern of Mud (%) and Sand (%) in the surface sediments along Dubai Creek during 2000*

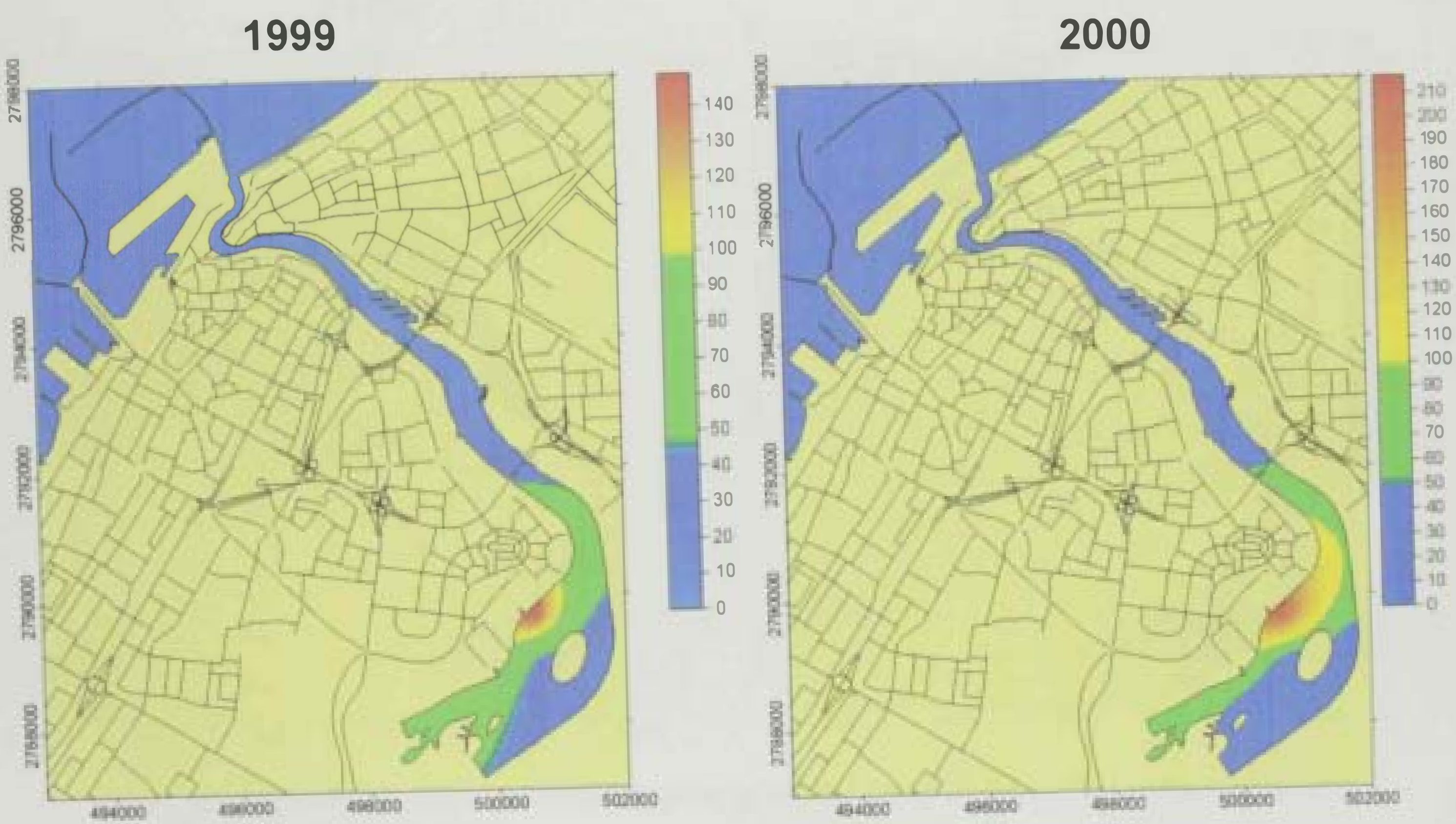


Figure 5.11 *Model showing annual distribution of Copper (ppm) in the surface sediments along Dubai Creek during 1999-2000*

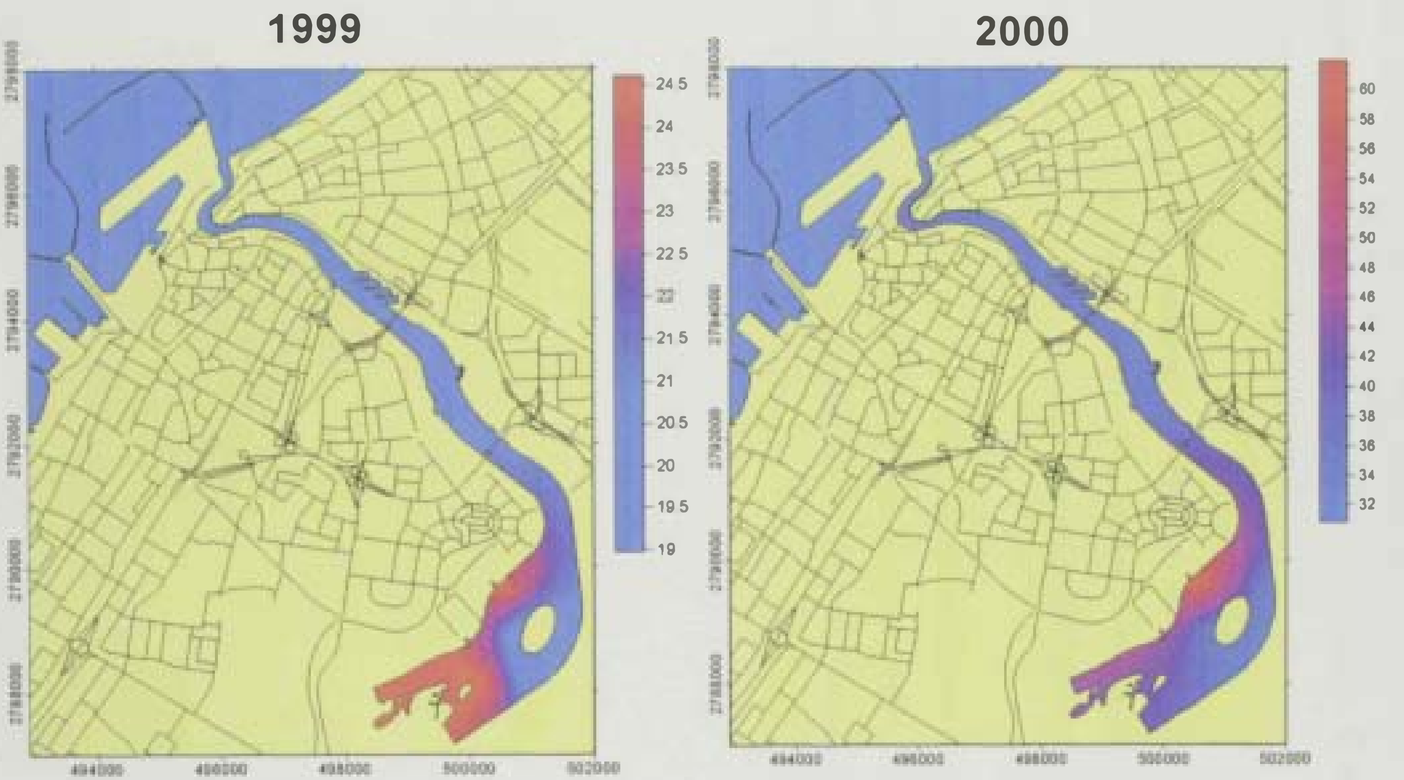


Figure 5.12 *Model showing annual distribution of Nickel (ppm) in the surface sediments along Dubai creek during 1999- 2000*

Lead shows distinct trend of distribution during 1999 and 2000 (Figure 5.13). The higher levels in the downstream area during 2000 as compared to 1999 are mainly attributed to the surface runoff from the roads along the banks of Dubai Creek channel. In theupstream region, the levels of lead in the surface sediments were lesser than 1999. The probable reasons in the reduction of these levels could be associated with the absance of lead in the discharges, in addition to the sinking of this heavy metal into the subsurface bed.

Zinc in the surface sediments shows high levels arising from station 9 and moving towards station 4 (Figure 5.14). The model clearly demonstrates remarkable higher levels in the vicinity areas of station 9 during 2000 as compared to 1999.

Chromium shows a different trend of plume (Figure 5.15), high concentrations are noticed in the area surrounding station 10 during 1999 and 2000. Chromium shows similar trend during 1999 and 2000 with high levels beyond the Island in the lagoon.

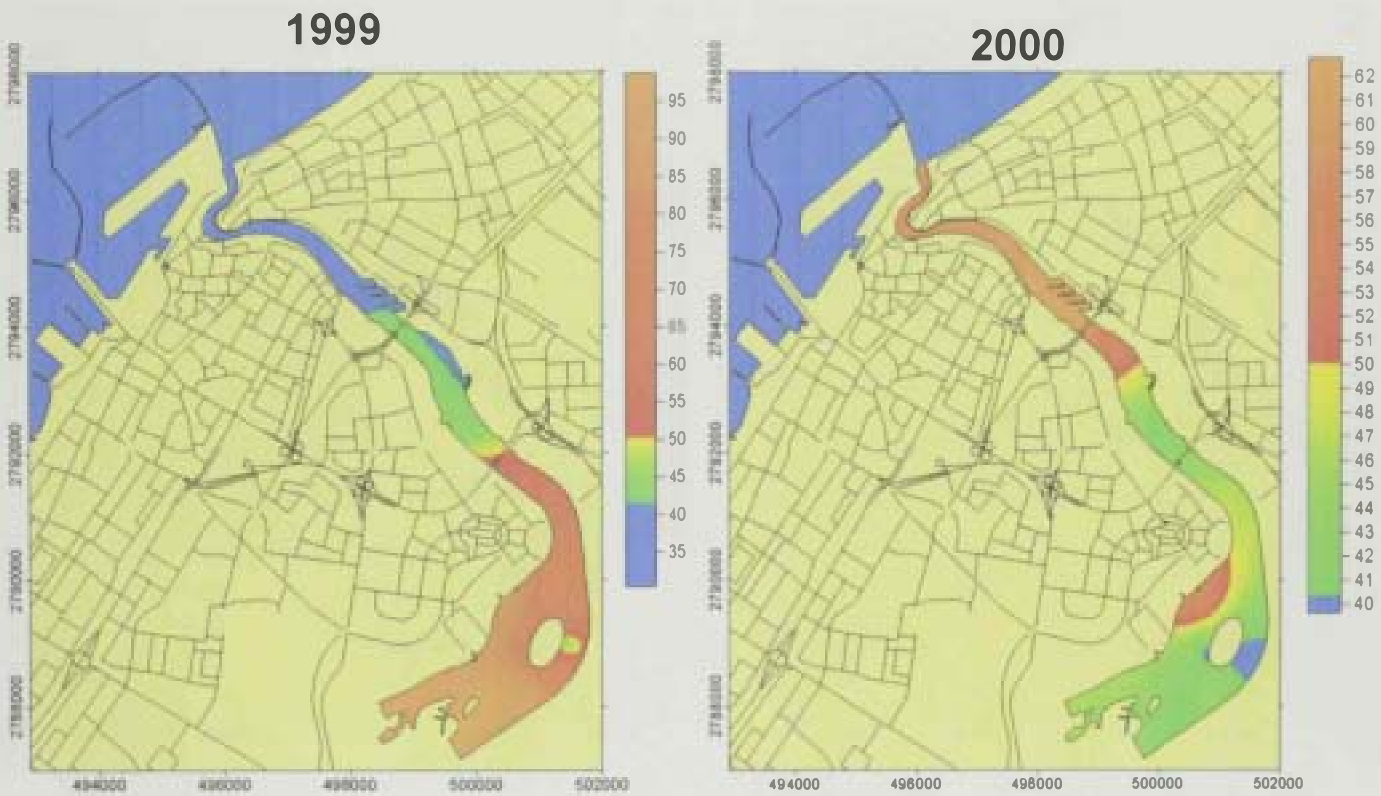


Figure 5.13 *Model showing annual distribution of Lead (ppm) in the surface sediments along Dubai Creek during 1999-2000*

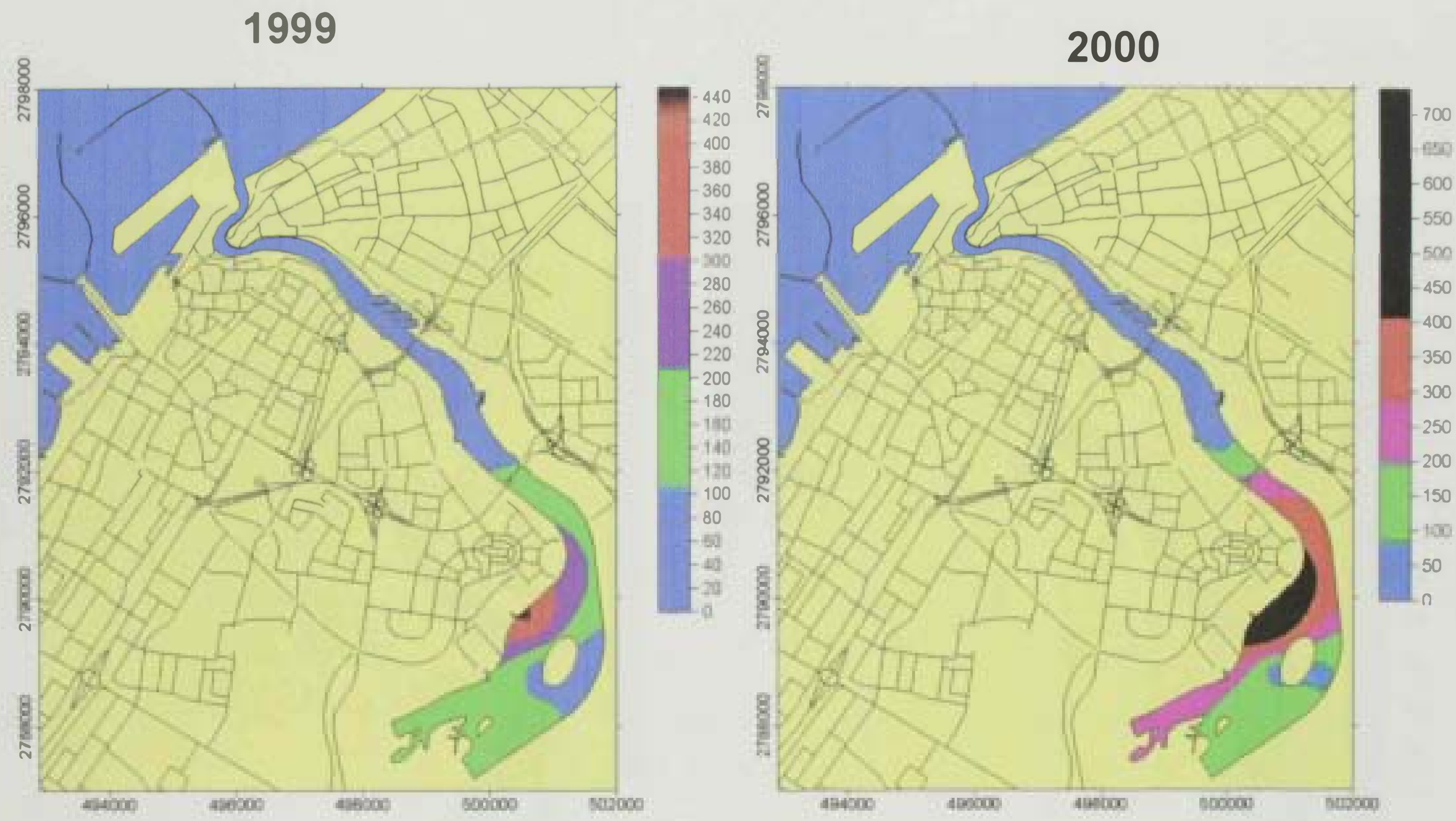


Figure 5.14 *Model showing annual distribution of Zinc (ppm) in the surface sediments along Dubai Creek during 1999-2000*

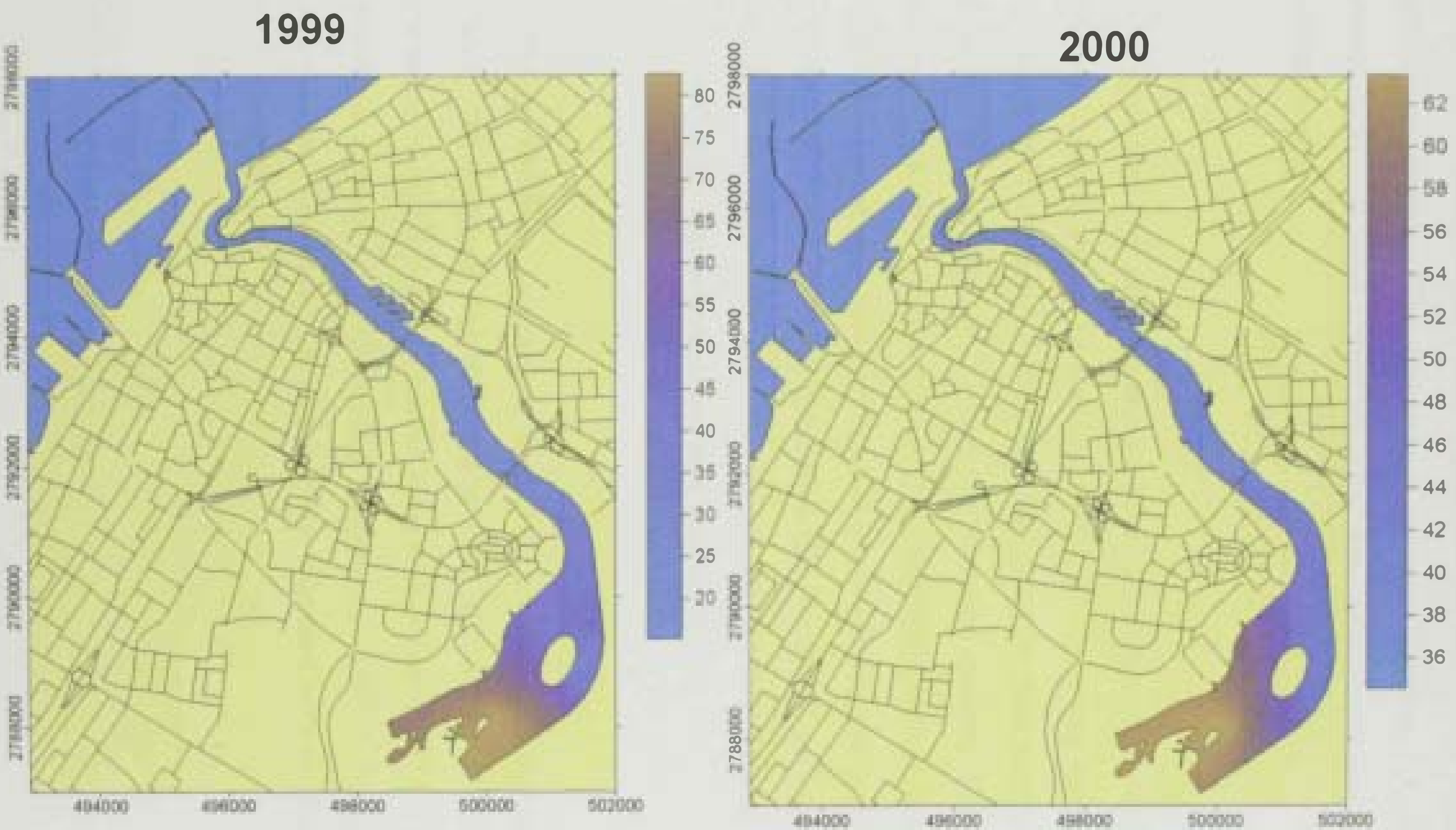


Figure 5.15 *Model showing annual distribution of Chromium (ppm) in the surface sediments along Dubai Creek during 1999-2000*

5.3 Discussion

The assessment of environmental capacity indicates the presence of at least two distinctive regions along Dubai Creek. These two regions can be well defined by their sediments characteristics. The first area is between stations 1-3, considered as the downstream region of Dubai Creek; while the area between stations 4-10 is defined as the upstream region.

The downstream and upstream regions have also distinct characteristics. According to Dubai Municipality studies (Halcrows, 1992), the upstream region has poor tidal current, the narrow entrance of the Creek increases the tidal current flow, while the wide head at the upstream region decreases the tidal current. Therefore, pollutants entering beyond station 4 are slow to reach the head of the lagoon, but at the same time any pollution reaching the upstream region of the Creek get entrapped instead of getting flushed off. The important point from this assessment indicates that pollutants from the upstream region are also not bound for the downstream region, so they accumulate within the region and behave as a sinking source.

Physico-chemical parameters in Dubai Creek show slightly low levels of salinity along the upstream region, which in turns affects pH and DO levels (Table 5.1). The negative correlation between DO and salinity shows that the DO is increasing when salinity is decreasing (Figure 5.18). Solubility of gases is inversely proportional to the salt contents. The same results have been coincided with the studies of Saltpans of Bombay (Mustafa, 1995).

Table 5.1 *Physico-chemical aspects of water quality along downstream, and upstream regions of Dubai Creek along during 1999-2000*

Parameters	**Averages Downstream level**	**Averages Upstream level**
Temperature (° C)	28.0	28.0
Salinity (‰)	39.5	38.9
PH	8.4	8.6
DO (mg/ℓ)	5.9	6.1

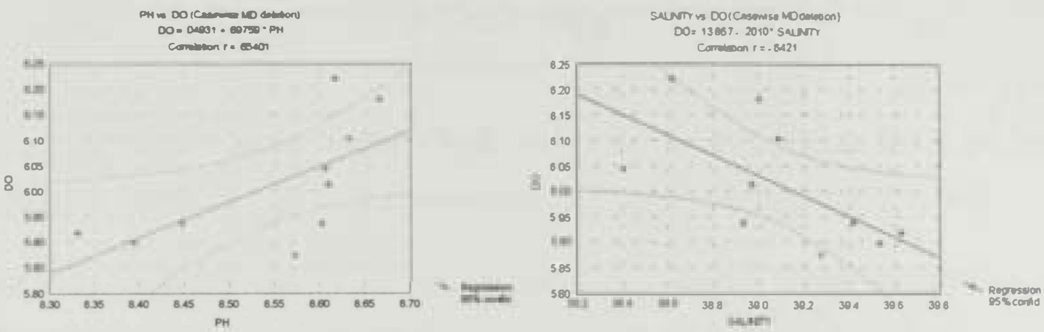


Figure 5.16 *Scatter plots showing the relationship between DO, pH, and salinity along Dubai Creek during 1999-2000*

Turbidity and nutrients levels are also in high concentrations levels in the upstream region of Dubai Creek as compared to the downstream region (Table 5.2).

Table 5.2 *Turbidity and Nutrients average levels along downstream, and upstream regions during 1999-2000*

Parameters	**Averages Downstream level**	**Averages Upstream level**
Turbidity (NTU)	1.4	2.4
Total nitrogen (μg-at/ℓ)	42.9	121.4
Nitrate-nitrogen (μg-at/ℓ)	14.3	50.0
Phosphate-phosphorus (μg-at/ℓ)	1.6	14.2

The levels of mud are high in the upstream region and as consequence increase the levels of organic carbon and moisture content (Table 5.4) .

Table 5.3 *Average Levels of sediment quality parameters along downstream, and upstream regions during 1999-2000*

Parameters	Averages Downstream level	Averages Upstream level
Moisture Content (%)	21.6	47.9
Organic Carbon (%)	1.1	3.3
Sand (%)	98.8	94.3
Mud (%)	1.2	5.7

Surface sediment along Dubai Creek shows remarkably higher levels of heavy metals in the upstream region as compard to the downstream region (Table 5.4)

Table 5.4 *Heavy metals levels in the surface sediments along downstream, and upstream regions during 1999-2000*

Parameters	Averages Downstream level	Averages Upstream level
Copper (ppm)	6.7	51.3
Nickel (ppm)	27.5	30.7
Lead (ppm)	48.7	58.4
Zinc (ppm)	16.6	180.4
Chromium (ppm)	30.0	49.9

Principal component factor analysis (PCA) is a multivariate technique for examining the structure of large data-arrays, and for reducing their dimensionality. It expresses the total variance of the array in terms of a small number of principal components (Eigen vector) (Rock, 1988). Strictly, principal components analysis is a mathematical calculation and not a statistical procedure (Rock, 1988).

It can be regarded simply as an ordination technique, for reducing multivariate data into fewer dimensions. It transforms an original set of N variables into a net set of N principal components.

In the present study PCA has been used in order to perform an assessment of metal pollution in accordance with environmental parameters of Dubai Creek. The first PCA mainly represents interrelationship between different environmental parameters (Figure 5.19). It consist of 10 cases and 8 variables (temperature, pH, salinity, DO, turbidity, total-nitrogen, nitrate-nitrogen, and phosphate-phosphorus). Both factors 1 and 2 weigh on their negative side of salinity and temperature. On the other hand, Factor 1 loads most parameters on its positive side while Factor 2 weigh turbidity, and DO on its negative side along with salinity and temperature.

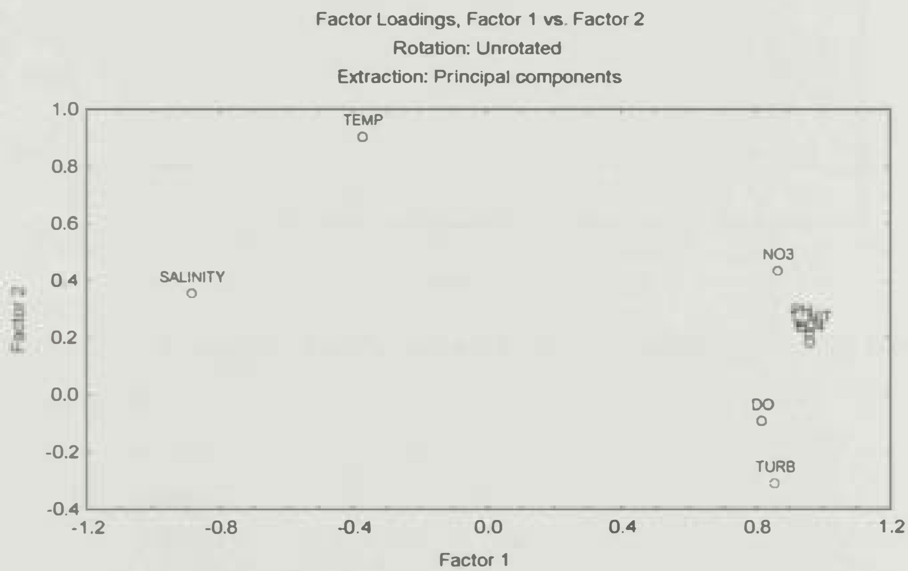


Figure 5.17 *Factor analysis of water quality parameters along Dubai Creek during 1999-2000*

The second PCA is performed for the sediment characteristic data (Figure 5.20). Ten cases and 9 variable of sediment quality (Moisture content, sand, mud, organic carbon , copper, nickle, lead, zinc, and chromium) were used in the PCA. The organic carbon.

moisture content, mud, and chromium are clustering together and making one cluster; while copper, nickel, lead, and zinc making another cluster. Both factors show sand on their negative sides. This reflects that sand on the negative side of all heavy metals, organic carbon, moisture content and mud. Hence, when sand decreses this means that mud, heavy metals, mositure content and organic carbon increase. The association of chromium with organic carbon indicates that chromium is forming a metal-organic complex. This may explain that chromium is the only metal that has its maximum values at station 10 rather than 9.

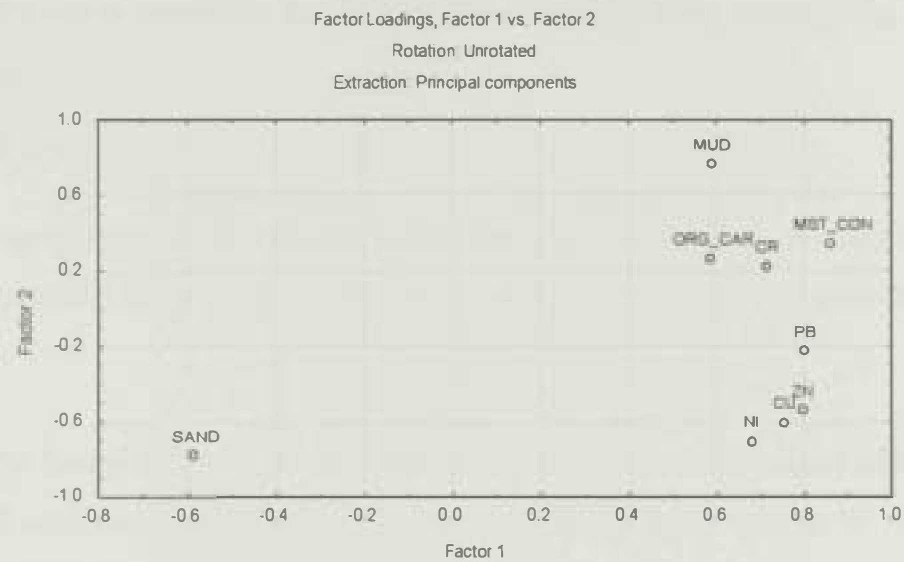


Figure 5.18 *Factor analysis for the sediment quality parameters along Dubai Creek during 1999-2000*

Overall, it is concluded that:

1. The water quality and sediment characteristics have made two distinct regions in Dubai Creek, the downstream (stations 1-3) and the upstream (stations 4-10) regions.

2. The variation in the water quality parameters such as temperature, pH, salinity, and DO is less prominent than turbidity, and nutrient along downstream, and upstream regions.

3. The differences in sediment quality are quite outstanding, the upstream region is sustaining higher level of heavy metals as compared to the downstream region.

4. The heavy metals increase in the upstream region are associated with the decrease of sand and the influx of mud contents and organic carbon, as well as the low flushing rate.

5. Station 9 is the main source of heavy metals (lead, copper, and zinc) and consequently it influences the high concentraion of heavy metals in the sediments of upstream region of Dubai Creek.

***

CHAPTER VI

SUMMARY AND CONCLUSION

Summary and Conclusion

The area investigated covers Dubai Creek on the Arabian Gulf. The Creek extends inland for 14 km from its entrance to the Arabian Gulf. The comprehensive pressure of urban development along both the banks has virtually made tremendous changes in the water quality and sediment characteristics in the Creek.

Ten stations were selected to study the area covering maximum fragments of the Creek. In addition to this, the available information on heavy metal concentrations in the surface sediments from one reference station of the protected coastal environment of Jabal Ali Sanctuary, where the urban and industrial activities are negligent are taken as a reference station.

Seasonal data on water quality parameters are collected from each stations in the Creek for a period of 24 months from January 1999 through December 2000. Surface sediments were sampled annually during 1999 and biannually during 2000.

Sediments short core fractions samples for mineralogy analyses from the different fractions of the short core was collected only from the upstream stations during 2000. For each water sample, physico-chemical parameters such as temperature, pH, salinity, and DO as well as turbidity and nutrients (total nitrogen, nitrate-nitrogen and phosphate-phosphorus) were determined. The surface sediments were analysed for copper, lead, nickel, zinc, and chromium concentrations. Moisture content, organic carbon, and sediment texture analysis in the surface sediments are conducted for all stations, while the mineralogy is studied in the short cores for minor, major, and subordinate minerals.

Surfer 7.01™ is the software package used to formulate models of water and sediment quality; whereas the Statistica™ is used to determine statistical applications.

Temperature variations in waters along Dubai Creek are generally associated with the prevailing air temperature. As for pH the Creek is entirely alkaline and is generally higher at the surface water. Low salinity values towards the southwest area of the Island along the upstream region of Dubai Creek indicates the influx of freshwater. DO levels in the Creek are closer to the saturation level particularly in the downstream region. However, in the upstream region high and low levels of DO at the surface and bottom waters were respectively recorded. Turbidity and nutrients (total nitrogen, nitrate-nitrogen, and phosphate-phosphorus) exhibit lower levels in the downstream as compared to the upstream region.

Sediments show high contents of moisture, organic carbon, and mud along the upstream region of the Creek. Station 9 shows a clear plume of high heavy metals (zinc, copper, lead, and nickel) concentration in the sediment. However, nickel plume in the surface sediments covers almost the entire upstream region. On the other hand, chromium shows a different trend of concentrations in the surface sediments, the highest concentration being noticed in the vicinity of station 10.

The highly negative correlation of salinity versus heavy metals indicates the association of these pollutants with freshwater anthropogenic releases into the Creek.

From the overall estimation it can be concluded that

1. Dubai Creek is characterized by two distinct geochemical features, one is identified as a polluted upstream region, whereas the other one is comparatively less polluted downstream region.

2. The level of heavy metals in Dubai Creek are 8 times higher in the downstream region (stations 1-3) and 23 times higher in the upstream region (stations 4-10) than the reference station of Dubai Coastal Environment (Jabal Ali Sanctuary).

3. The negative relationship between heavy metals and salinity along Dubai Creek is adequate enough to demonstrate that the pollutants in the Creek sediment are derived from anthropogenic releases.

4. The area surrounding station 9 in the upstream region is the most contaminated. The major source of anthropogenic pollutants inputs is the discharge located near this station.

5. Accumulation rate of heavy metals in the sediments at station 9 is estimated at: 0.85 ppm for zinc, 0.10 ppm for copper, 0.17 ppm for nickel, and 0.03 ppm for chromium per day.

6. Lead and zinc levels in the surface sediments of Dubai Creek are 35 times higher than the levels found in unpolluted marine sediments of U.A.E. as recorded in 1993.

7. The levels of nutrients such as total nitrogen, nitrate-nitrogen and phosphate-phosphorus are 2.8, 3.5, and 8.8 times respectively higher at the upstream region as compared to the nutrients in the downstream region.

8. Based on the present investigations, it can be concluded that the environmental quality of the upstream region of Dubai Creek is deteriorated due to the waste inputs from the land based discharges. Heavy metals in the surface sediments of the uptream region of Dubai Creek are associated with anthropogenic freshwater releases from Outfalls 24, 18, and 17.

9. The movement of pollutants inside the upstream region of Dubai Creek is restricted and localized, for the Creek is an enclosed water body associated with the poor rate of tidal flushing .

10. The protection and management of marine environment through proper strategies require monitoring and controling strategies on these discharges by strict enforcement of the legislations. Although, there are specified limits stipulated in the local order No. 61 of 1991 on the environmental protection in the Emirate of Dubai, however, the ammendments in the discharge limits into the marine environment should be reviewd and dredging prospects in Dubai Creek should be considered carefully .

***

RECOMMENDATIONS

Based on data gathered during this study, a conclusion can be drawn that nutrients and heavy metals undoubtedly pollute the upstream region of Dubai Creek. The studied pollution indicators are adequate to understand behavior of the pollutants in the upstream region of Dubai Creek. Ignorance of existing conditions will certainly shape worse setting in Dubai Creek environment. Therefore, a comprehensive management plan is needed for the sustainable development of Dubai Creek. Urgent steps need to consider the following: -

- Relocation of STP discharge into the coastal belt;
- Complete treatment of discharge from outfall No. 24, located in Jaddaf, furthermore, the mode of discharge should be done through the diffuser system;
- The Top sediment layers in the upstream region ought to be dredged;
- A three-dimensional water quality and sediment characteristics model, that clearly demonstrates the problems in the various regions of Dubai Creek need to be available for the decision-makers.
- Around the clock fortnightly water quality and biological characteristics monitoring in the upstream region of Dubai Creek need to be carried out.
- Wastewater quality monitoring from outfalls Numbers 16, 18, and 22 located in the upstream region of Dubai Creek shall be conducted.

***

REFERENCES

REFERENCES

- Abayachi, J.K. and Douabul, A.A.Z. (1986) Trace element geochemical association in the Arabian Gulf. Mar. Poll. Bull. **1**: 353 - 356.

- Abu-Hilal, A.H. and Adam A. (1995) Sources, levels and distribution of nutrients and other pollution indicators in Dubai and Abu Dhabi Creeks and near shore waters (United Arab Emirates). J.Fac. Sci. U.A.E. Univ. **7(4)** :56-79 p.

- Abu-Hilal, A.H. and Bardan, M.I. (1990) Effect of pollution sources on metal concentration in sediment cores from the Gulf of Aqaba (Red Sea). Mar. Poll. Bull. **21**: 190 -197.

- Abu-Hilal, A.H. and Khordagui, H.K. (1992) Heavy metals in Creeks and near shore sediment of the United Arab Emirates: The Arabian Gulf and Gulf of Oman. Desert and Marine Environment Research Center, U.A.E University. 33 pp. (unpub. Man.)

- Abu-Hilal, A.H., Qasimi, R.A.A. and Adam, A.B (1990) Observations on the status of coastal and Creek waters of the United Arab Emirates: 1- Nutrients Symposium on Marine Chemistry on the Arab Region. UNESCO-National Oceanographic Center, Suez, Egypt. 20-23 April, Suez, Egypt.

- Al-Abdali, F., Massoud, M.S., and Al-Ghadban (1996) Bottom Sediment of the Arabian Gulf-III. Trace Metal Content as indicator of pollution and implication for the effect and fate of the Kuwait Oil Slick. Environmental Pollution: **93**: 285-301.

- Al-Arfaj, A.A. and Alam, I.A. (1993) Chemical characterization of sediment from the Gulf area after 1991 oil spill. Mar. Poll. Bull. **27**:97-101.

- Al-Ghadban, A., Massoud M., Al-Abdali, F. (1996) Bottom sediment of the Arabian Gulf: I. Sedimentological characteristics. Kuwait Journal of Science and Engineering. **23**: 71-88.

- Al-Hashimi, A.H. and Salman H.H. (1985) Trace metals in the sediments of the northwestern coast of the Arabian Gulf. Mar. Poll. Bull. **3**: 118 - 120.

- Aller, R.C., Mackin, J.E., Ullman, W.J., Chen-Hou, W., Shing-Min, T., Jian-Cai, J., Young-Nian, S., and Jia-Zhen, H.(1984) Early chemical digenesis, sediment-water solute exchange, and storage of reactive organic matter near the mouth of the Changjiang East China Coast. Continental Shelf Research: **4**: 227-251.

- Al-Qubaisi, N (2001) Assessment of metals pollution in sediments of the coastal area, U.A.E. MSc. Thesis, Environmental Science Programme, U.A.E University, 134 pp. (unpub. thesis).

- Anderlini, V.C., Mohammed, O.S., Zarba, M.A., Awayes, R.A. and Al Jalili R. (1982) An assessment of trace metal pollution in the Kuwait marine environment. First Arabian Gulf Conference on Env. and Poll.7-9 February 1982.

- Anderlini, V.C., Mohammed, O.S., Zarba, M.A., Fowler, S.W. and Miramand, (1986) Trace metals in marine sediments of Kuwait. Bul. Environ. Contam. Toxical. **28**: 75 – 80.

- APHA. (1995) American Public Health Association (APHA), Amer. Water Works Assn., Water Pollution Control Fed. 1971. Standard Methods for Examination of Water and Wastewater 19th ed. Amer. Public Health Assn. New York, N.Y.

- Basaham, A.S. and Al-Lihaibi, S.S. (1993) Trace Elements in sediments of the Western Gulf. Mar. Poll. Bull. **27**: 103-107.

- Basaham, A.S. and El-Sayed M.A. (1997) Distribution and phase association of some major and trace elements in the Arabian Gulf sediments. Estuarine, Coastal and Shelf Science **46**: 185-194.

- Basaham, A.S.(1997) Distribution and behavior of some heavy metals in the surface sediment of Al-Arbaeen Lagoon, Jeddah, Red Sea Coast. Earth Science **10**: 59-71.

- Basson, P., Burchrd, J.H., and Price A., (1977) Biotopes of the Western Arabian Gulf. ARAMCO Dept. Loss. Prev. and Env. Affairs Dhahran, S. Arabia.

- Brewer, P. and Dyrssen, D. (1985) Chemical Oceanography of the Persian Gulf. Progress In Oceanography, **14**: 41- 55.

- Brewer, P. G., Fleer,A., Kadar,S., Shafer, L. (1978) Chemical Oceanographic data from the Persian Gulf and Gulf of Oman Report. A Woods Hole Oceanographic Institution WHOI 1978 **38**: 105 pp.

- Brooks, R.R., Presley, B.J. and Kalplan, I.R (1967) Trace elements in the intertidal waters of marine sediments. Geochemica et Cosmochimica Acta **32**: 397- 414 Pergamon Press, N. Ireland

- Bryan, G.W. (1976) Heavy metal contamination in the sea. In marine pollution edition. R. Johnstten. Academic Press, London, U.K, 185-302 p.

- Davis, J.C. (1973) Statistics and Data analysis in geology, 1st ed. Wiley, New York, 550 p.

- Dahab, O.A., and Al-Madfa, H. (1996) Chromium distribution in waters and sediments of the eastern side of the Qatari Peninsula. The Science of the Total Environment **196**: 1-11.

- Dorgham, M., El-Gindy, A. (1991) Seasonal variations and inter-relations between the phytoplankton count and the hydro chemical factors in Qatari waters of the Arabian Gulf. Proceeding Symposium on Environmental Studies and Pollution, Alexandria University, Center of Post Graduate Studies, Egypt.

- Dorgham, M., Muftah, A., and El-Deeb, K.Z. (1987) Plankton studies in the Arabian Gulf. II. The Autumn phytoplankton in the northwestern area, Arab Gulf J. Sci. Res. Agric. Biol. Sci. **B5(2)**, 215-235 p.

- Dubai Municipality. (1995a) Mass Mortality of Fish *Nematalosa nasus* along the lagoon of Dubai Creek during October 1995. EPSS, Dubai Municipality, 1995 35 pp. (unpub. report)

- Dubai Municipality. (1996a) Impact of rain runoff on the water quality of Dubai Creek during 1996. EPSS, Dubai Municipality, 1996 21 pp. (unpub. report)

- Dubai Municipality. (1996b) Biological Characteristics of Dubai Marine Environment. EPSS, Dubai Municipality, 1996 30 pp. (unpub. report)

- Dubai Municipality. (1997a) Impact of rain runoff on the water quality of Dubai Creek during 1997. EPSS, Dubai Municipality, June 1996 34 pp. (unpub. report)

- Dubai Municipality. (1997b) Problem of Eutrophication in the lagoon of Dubai Creek. EPSS, Dubai Municipality, 1997 45 pp. (unpub. report)

- Dubai Municipality. (1997c) Seasonal algal bloom along Dubai Creek. EPSS, Dubai Municipality, 1997 30 pp. (unpub. report)

- Dubai Municipality. (2000a) Annual Water Quality bulletin (1999 and 2000).EPSS, Dubai Municipality 2000. 40 pp. (unpub. report)

- Dubai Municipality. (2000b) Quarterly, Bi-annual and Annual bulletin of Marine Water Quality (1994-1998). EPSS, Dubai Municipality 2000 60 pp. (unpub. report)

- Dunne, T., and L.B. Leopold. 1978. Water in Environmental Planning. W.H. Freeman and Company, NY.

- Edward A. L. (1993) Aquatic Pollution- An introduction text, John Wiley and Sons Inc. 611 pp

- Eisler, R., Lapan R.L., Talek, G., Davey , E.W., Soper, A.E. and Barry M., (1977) Survey of metals in sediments near Quonset Point, Rhode Island, Mar. Poll. Bull. 8: 260-264.

- El-Baz, F. and Makharita, R.M. (1994) The Gulf war and the environment, Gordon and Breach Science Publishers, 206 p.

- El-Gindy, A. and Dorgham, M. (1982) Inter-relationship between phytoplankton counts, chlorophyll and hydrochemical factors in the Arabian Gulf and Gulf of Oman, during summer. Indian J. Marine Science (In press).

- El-Sammak, A. (1995) Assessment of metals pollution in the sediments of lake Burullus, S.E. Mediterranean, Egypt. Qatar Univ. Sci. J **15**: 451-455.

- El-Sammak, A. (2000) Geochemical associations in the marine sediments off Ras Al-Khaimah, United Arab Emirates. In: Mohamed, A.M.O. (eds). Geoengineering in Arid Lands. A.A. Baekema, Rotterdam. 473-480 p.

- El-Sammak, A. (2001) Heavy metals pollution in the bottom sediments, Dubai, UAE. Bull. Enviro. Contamination and Toxicology, **67**: 294-302

- El-Sammak, A. and Aboul-Kassim. (1999) Metal Pollution in the sediment of Alexandria region, southern Mediterranean, Egypt. Bull. Environ. Contam.Toxicol **63**: 263-270.

- El-Sayed, M.Kh. (1982) Effect of Sewage effluent on the sediments of Nordasvathet (a land-locked fjord). Norway. Mar. Poll. Bull. **13**: 85-88.

- Föstner, U. and Wittman, G.T.W. (1981) Metal Pollution in Aquatic Environment 2nd Edition 1981- Springer- Verlag, Berlin - Heiddelburg, New York 486 p.

- Fowler, S.W. (1985) Coastal baseline studies of pollutants in Bahrain, U.A.E, and Oman ROPME. Symposium on Regional MARINE Monitoring and Research Programmes, UA.E. University Al-Ain. 8-11 Decemeber 1985.

- Fowler, S.W. (1990) Critical review of selected Heavy metals and chlorinated hydrocarbons in the Marine Environment. Mar. Env. Res. **29** : 1-64.

- Fowler, S.W., Readman J., Oregioni, B., Villeneuve, J., McKay, K. (1993) Petroleum Hydrocarbons and Trace Metals in near shore Gulf Sediment and Biota before and after the 1991 Gulf war: An Assessment of Temporal and Spatial Trends. Mar. Poll. Bull, **27**: 171-182.

- GESAMP (1986) (IMO/FAO/UNESCO/WMO/WHO/IAEA/UN/UNEP Joint Group of Experts on the Scientific Aspects of Marine Pollution), Environmental Capacity. An approach to marine pollution prevention) (1986). Rep. Stud. GESAMP, 30: 49 p.

- GESAMP (1991) (IMO/FAO/UNESCO/WMO/WHO/IAEA/UN/UNEP Joint Group of Experts on the Scientific Aspects of Marine Pollution), Coastal Modeling (1991). Rep. Stud. GESAMP. 43:189 p.

- Gaudette, H.E., Flight, W.R., Toner, L. and Folger, D.W.(1974) An inexpensive titration method for determination of organic carbon in recent sediments. J. Sed. Petrol. **44**: 249-253.

- Grasshoff, K. (1976) Review on hydrographical and productivity conditions in the Gulf Region. UNESCO Technical paper in marine Science, **26**: 39 – 62.

- Grice, G. D. (1978) General biological and oceanographic data from the Persian Gulf and Gulf of Oman Report. B Woods Hole Oceanographic Institution WHOI 1978. **38**: 35 pp.

- Halcrows. (1992) Improvement of Dubai Creek. Studies conducted by Halcrows International Partners. Dubai Municipality, 1992.(unpub. report).

- Hardisty, J., Taylor, D.H. and Metcalfe, S.E. (1993). Computerized Environmental Modeling. A Practical Introduction Using Excel. John Wiley & Sons Ltd. Chichester. 203 p.

- Hunter, J. (1982) The physical oceanography of the Arabian Gulf: A review and theoretical interpretation of previous observations. Paper presented at First Gulf Conference on Environment and Pollution, Kuwait.

- Hunter, J. (1986) The Physical oceanography of the Arabian Gulf: A review and theoretical interpretation of the previous observation. In: Marine Environment and Pollution, Proceeding of the First Arabian Gulf Conference on Environment and Pollution. Eds. Halwagy R., Clayton D., Behbehani M. Kuwait University, Faculty of Sciences, KFAS and EPC, Kuwait, 1 - 25.

- IAEA. (1999) IAEA/ROPME 1998 Contamination Screening Project. First Mission Report, October 1999 (unpub. report).

- Ismail, N. S. (1992) Macrobenthic Invertebrates near sewer outlet in Dubai Creek, Arabian Gulf. Mar. Poll. Bull. Vol 24: 77-8.

- Kouadio, I. and Treffy, J.H. (1986) Sediment trace metals contamination in the Ivory Coast, West Africa, Water, Air and Soil Pollution 32: 145-154.

- Jaworski, N.A. 1981. Sources of Nutrients and the Scale of Eutrophication Problems in Estuaries. p. 83 in in Estuaries and Nutrients, Nielsen, B.J., and L.E. Cronin (eds.) 1981. Humana Press: Clifton, NJ.

- Kureishy T.W. and Ahmed M.H (1994) Total Mercury distribution in surface sediment from the Arabian Gulf. Qatar Univ. Sci. J. 14(2): 390-394.

- Loring, D.H. and Rantala, R.T.T (1991) Manual for the geochemical analyses of marine sediment and suspended particulate matter. Earth Science Review, 32(1992): 235-283.

- MNR-Bahrain. (2000) Marine National Report- State of the Marine Environment. Ministry of Housing, Municipalities and Environmental Affairs, Directorate of Environmental Assessment and Planning Bahrain.

- MNR-Kuwait. (1999) Marine National Report- National Report on State of Marine Environment in Kuwait. Environment Public Authority, Kuwait.

- MNR-Oman. (1999) Marine National Report- State of the Marine Environment. In Sultanate of Oman, Municipalities and Environmental Affairs, Co-ordination and Follow up Department- Sultanate of Oman.

- MNR-Qatar. (1999) Marine National Report- State of the Marine Environment in the state of Qatar. Ministry of Municipalities and Agriculture, Environment Department, Qatar.

- MOOPAM. (1999) Manual of Oceanographic Observation and Pollutant Analysis Methods. Regional Organization of Protection for the Marine Environment, Kuwait.

- Mustafa, S. (1995) Ecology of plankton from Saltpans along the coastal Environment of Bombay, University of Bombay (unpub. thesis).

- Mustafa, S., Deshgooni M.A. and Salman R.H. (2001) Problem of Eutrophication in the Lagoon of Dubai Creek. Int. Con. Management of Marine Environment in the Arabian Gulf' 21-23 October 2001, Al-Ain U.A.E.

- NIO (1992) Release of industrial wastewater in Vashisti Estuary and environmental impact prediction-National Institute of Oceanography, India March 1992 59 pp.

- NOAA/EPA. National Oceanic and Atmospheric Administration and Environmental Protection Agency. 1988. Strategic Assessment of Near Coastal Waters, Chapter 3, Susceptibility and Concentration Status of Northeast Estuaries to Nutrient Discharges. NOA A: Washington, D.C.

- Parsons, T.R., Yoshiaki, M. and Karol, M.L.(1984) A Manual of chemical and biological methods for Seawater analysis. First Edition . A. Whiton, Great Britain.

- Redfiled, A. C. (1934) On the proportion of organic derivatives within the depth of the Atlantic Ocean. PAP. Phys. Ocean. Met. 9, 1-22

- Reynold, R. (1993) Physical oceanographic of the Gulf, Strait of Hormuz, and the Gulf of Oman: Results from Mt. Mitchell Expedition. Mar. Poll. Bull. 27: 35-39.

- Rock, N.M.S. (1988) Numerical Geology, Lecture notes in Earth science. V.18. Springer-Verlag, New York-Tokyo. 427 p.

- ROPME. (2000) Regional Report of the State of the Marine Environment, Regional Organization of Protection for the Marine Environment, Kuwait.

- Ross, D. A. (1978) General data on bottom sediments including concentration of various elements and hydrocarbons in the Arabian Gulf- Report C geophysical nature of the Persian Gulf and Gulf of Oman Report D Woods Hole Oceanographic Institution WHOI 78-39: 107 p.

- Saad, M.A. and Hussein, N.A. (1978) Preliminary studies on sodium, magnesium, calcium, potassium in the north-west Arabian Gulf, The Arabian Gulf 9: 19-27.

- Sadiq, M. and McCain, J.C. (1993) The Gulf war aftermath: an environmental tragedy. Kluwer Academic Publishers 298 p.

- Salman, R. (1999) Assessment of Dubai Creek eutrophication and development strategies. London School of Economics and Political Science, M.Sc., thesis 59 p (unpub. thesis)

- Samhan, O., Anderlini, V. and Zarba, M. (1979) Preliminary investigation of the trace metal levels in the sediments of Kuwait. Kuwait Inst. Scientific Research, Ann. Sci. Rep. 1979: 93-96.

- Schindler, D.W. 1978. Factors regulating phytoplankton production and standing crop in the world's freshwaters. Limnology and Oceanography 23:478-486.

- Sheppard, C., Price A., Roberts C. (1992) Marine Ecology of the Arabian Region: Patterns and Processes in Extreme tropical environments. Academic press London.

- Shriadah, M. (1999) Heavy metals in mangroves sediments of the United Arab Emirates shoreline (Arabian Gulf). Water, Air and Soil Pollution, **116**: 523-534.

- Shriadah, M. and Al-Ghais, S. (1999) Environmental Characteristics of the United Arab Emirates water along the Arabian Gulf. Hydrographic survey and Nutrients slate. Indian Journals of Marine Science. **28**: 225-232.

- Salomons, W. and FÖrstner, U. (1984) Metals in Hydrocycle. Springer-Verlag, Berlin.Germany.

- Tomlinson, D.L., Wilson, J.G., Harris, C.R. and Jeffery, D.W. (1980) Problems in assessment of heavy metals levels in estuaries and the formation of a pollution index. Helgol Meeresunters **33**: 566-575.

- UNEP. (1985) Symposium / workshop on oceanographic modeling of the Kuwait Action Plan (KAP) Sea region (1983: University of Petroleum and Minerals, Dhahran, Saudi Arabia) Regional seas. UNEP regional seas Reports and Studies; No. 70.

- UNESCO. (1984) Symposium / workshop on Oceanographic Modeling of the Kuwait Action Plan (KAP) Sea region (1983: University of Petroleum and Minerals, Dhahran, Saudi Arabia) Regional seas. UNEP Report in Marine Science; No. 28.

- USEPA. U.S. Environmental Protection Agency. 1986. *Ambient Water Quality Criteria for Bacteria - 1986*. EPA 440/5-84-002

- Wilson, G. and Shukla, R. (1999) Father of Dubai, Sheikh Rashid Bin Saeed Al Maktoum. Media Prima, Dubai, First Edition 1999. 228 pp.

- Windom, H. L., Steven J. S., Fred D. C., Joseph D. R., Ralfh G. S., Luis C. B., Frank G. L. and Charles H. R. (1989) Natural trace metal concentrations in estuarine and coastal marine sediments of the Southern United States. Environmental Science and Technology, Vol :**23** (3) 314-320, 1989.

- Young, D.R., Young, C.S. and Hlavka, G.E. (1973) Sources of trace metals from highly-urbanized Southern California to the adjacent marine ecosystem. In cycling and control of metals. 21-39 p, U.S. Environment Research Center, Cincinnati, O.H.

***

الخلاصة

تشمل منطقة البحث خور دبي بالخليج العربي. تم اختيار عشر محطات تغطي أقصى أجزاء الخور. دل تقييم " الاستيعاب البيئي" على وجود منطقتين مميزتين على الأقل. الأولى في الجزء السفلي من اتجاه مجرى الخور وتقع بين المحطات 1- 3 ، أما الثانية فتقع في أعلى مجرى الخور وتقع بين المحطات 4 - 10.

خضعت عينات المياه لتحاليل المؤشرات الفيزيوكيمائية (الحرارة ، الأس الايدروجيني، الملوحة، الأوكسجين المذاب، العكورة) والمغذيات (النيتروجين الكلي، نيتريت النيتروجين، وفوسفيت الفوسفور). أما عينات التربة السطحية فقد أجريت عليها تحاليل محتوى الرطوبة، والكربون العضوي، والتركيبة. وكذلك محتواها من حيث العناصر الثقيلة (النحاس، الرصاص، النيكل، الخارصين، والكروميوم).

أظهرت قراءات الملوحة المنخفضة في عمود المياه بأتجاه الأجزاء الجنوبية-الغربية للجزيرة الواقعة في منطقة أعلى مجرى الخور وجود مصدر للمياه العذبة فيها. أما مستويات المواد المغذية كالنيتروجين الكلي، نيتريت النيتروجين، وفوسفيت الفوسفور في مياه السطح فكانت مرتفعة بنسبة 2,8 ، 3,5 ، و 8,8 أضعاف على التوالي في الأجزاء الواقعة في منطقة أعلى مجرى الخور مقارنة بالأجزاء الواقعة في منطقة أسفل مجرى الخور.كما يلاحظ وجود تركيزات مرتفعة لمحتوى الرطوبة ، الكربون العضوي والطين في التربة السطحية على طول أجزاء منطقة أعلى مجرى الخور.

وبالنسبة للعناصر الثقيلة كالنحاس ، الخارصين، والرصاص فقد أظهرت الدراسة أن هناك منطقة مرتفعة التركيزات حول المحطة 9. كما دلت النتائج بأن الأجزاء المحيطة بالمحطة 9 تعد الأكثر تلوثا في منطقة أعلى مجرى الخور. أما التربة السطحية للخور فيزيد محتواها من حيث الرصاص والخارصين بنسبة 36 ضعفا عن مستويات التربة البحرية غيرالملوثة في دولة الأمارات مقارنة بالنتائج المسجلة في عام 1993.

*****

إهداء

إلى أهلي وزملائي والمنتفعين من هذا العمل.

محمد عبد الرحمن حسن دشكوني

ربيع الأول 1423هـ/ مايو 2002م

بسم الله الرحمن الرحيم

نمذجة و تقييم الحمل البيئي للمنطقة الساحلية
دبي – دولة الإمارات العربية المتحدة

أطروحة مقدمة لاستكمال متطلبات الحصول على
درجة الماجستير في علوم البيئة

محمد عبد الرحمن حسن دشكوني

عماده الدراسات العليا
برنامج ماجستير علوم البيئة
جامعة الإمارات العربية المتحدة
مايو 2002